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Laws, Regulations, and Environmental Factors and Their Potential Effects on the Stocks and Fisheries for the Blue Crab, Callinectes Sapidus, in the Chesapeake Bay Region, 1888-1940

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PREFACE

In the period 1880 to 1940, the blue crab fisheries of Chesapeake Bay evolved from a relatively small industry to one having a significant economic impact on watermen, processors and shippers, and the coastal communities, and the need for studied legislation and administration of the industry. The growth of the fishery resulted also in a need for well thought out science based on legislation and administration of the fishery. This text examines whether any of several variables had effects on the stocks and the successes or failures of the fisheries, with the aim of more informed planning of scientific studies, and recommendations to administrators.

The many changes after 1940, beginning with the establishment of a summer sanctuary in the southern end of the bay, the invention and extensive use of the wired crab pot, the advent of WWII and major changes in the size of the workforce, the availability of landings and effort data obtained first by the federal government and later by the states, and catch and biological data obtained by independent investigators, introduced a new set of variables to examine for their potential effects on the stock. Those changes require a major effort in analysis, which must be deferred until the present text is completed.

However, some review of the fisheries after 1940 has been included here to provide clarity and continuity, and whether later knowledge could contribute to a better interpretation of the effects of the many variables on stock success. Knowledge and the fisheries did not stop in 1940.

ACKNOWLEDGEMENTS

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ABSTRACT

Minimum size limits, fishing intensity, the protection of female crabs with extruded eggs, and variations in the physical and chemical conditions of the environment are suggested as factors that might have affected yearclass strength, and/or catch, from 1880-1940. The effects of severe weather on habitat quality and the behavior of crabs are largely unknown. Little is known of the intensity of fishing of any gear. Licenses were seldom required by the states over the first two-thirds of the period, and federal canvasses of landings and fishing effort were made only occasionally until 1929. Gear usage was not often interrupted by adverse weather, although gear and facilities that were destroyed in the August 1933 storm caused a major shift in gear types for several years. New kinds of gear and methods of fishing were seldom introduced. Three legislative changes that could have had a major impact on the stability of the bay's blue crab population were the 3.5 inch minimum width limit on hard crabs enacted by Virginia in 1912, the bi-state imposition of the 5-inch minimum width limit on hard crabs in 1916 and 1917, and the seasonal and geographic protection of sponge crabs enacted in 1916, 1917, 1922, 1926, 1932, 1934, and 1935-1940. However, despite those laws, wide and frequent fluctuations in catch and landings have characterized the blue crab fisheries. This does not mean that minimum size and sponge crab protection laws were ineffective, but that other factors could be either counteracting or enhancing them.

INTRODUCTION

The development of profitable fisheries and the occurrence of wide annual fluctuations in landings of blue crabs along the Atlantic and Gulf coasts of the United States create a demand for regional laws and regulations. Since the blue crab fisheries of the Chesapeake Bay are confined to state territorial waters, responsibility for fisheries management rests with Virginia and Maryland. Regulatory authority concerning licensing, quotas, seasons, gear restrictions, size and sex limits, and other controls over harvesting is generally retained by each state's general assembly, but some authority may be delegated to commissions to establish management action at the local level as the need arises.

Acts of the Chesapeake Bay state legislatures at the end of the 19th century and early in the 20th century and regulations passed by commissions decades later were promulgated to promote the wise use of the resource, to protect the blue crab population from practices that might lead to its endangerment, to alleviate declining fisheries, and to effect partitioning of seasons and/or areas whenever there was competition between the fisheries for the blue crab, or between the crab industry and the exploiters of other resources.

The overall objective of this book is to describe how the states responded to changing biological, economic, and perhaps political conditions in Chesapeake Bay; to explain trends in landings and indices of abundance derived from catch data; and to discuss whether rules and regulations could have had an effect on subsequent landings. The evolution of the rules and regulations is cited to alert the potential user of catch or landings data to those changes that might affect the organization of the data.

It is concluded that the basic factors that determine population size and the subsequent catch are minimum width limits and the seasonal and geographic protection of adult females carrying extruded eggs. However, the success of the hatch and survival of pre-adult stages of development of the blue crab from 1880 through 1940 were ultimately determined by the wide and frequent fluctuations in climatic events that modified the aquatic environment. Too little is known of the intensity of fishing in the 60-year period to evaluate any effect on subsequent year classes.

Economic and political events that occurred in the late 1930s and after 1940 encouraged major changes in the blue crab industry: the number and dedication of the watermen, processors and shippers; the introduction of new gears and the decline of older ones; the opening of new markets; and the enactment of new regulations and laws. Those changes require a different, and probably more difficult, analysis of the bay blue crab industry that should be considered elsewhere.

Early History of the Fisheries

Although there had been hard, soft, and peeler crab fisheries in the Chesapeake Bay before 1873, and crab abundance was reported to be high, consumer demand was primarily local. Shipments from the Chesapeake Bay region were unimportant. Fisheries in the coastal states north of Maryland, especially New Jersey and New York, amply provided for their own local consumer demands.

An intensive fishery for peeler crabs in Maryland in 1873 was spurred by the development of methods for shedding and shipping soft crabs for which there was high consumer demand and relatively high profit. Crab meat canning was initiated in 1878 in Virginia, encouraging a trotline fishery for hard crabs (Churchill, 1919a). Declines in the landings in New York and New Jersey beginning in 1889 encouraged shipping from the Chesapeake Bay states and the expansion of the fisheries (Baker et al., 1909; Lyles, 1967).

During the first 20 years of recorded history of the Chesapeake Bay crab industry, markets developed slowly and landings were small (Tables 1-2). Crabs were often considered a nuisance by-catch to more commercially valuable fish (Brooks, 1893).

Supervision of the Fisheries

Fish commissioners for Virginia were appointed as early as 1871 (Virginia State Library, 1917). Laws relating to the Virginia blue crab fisheries first appeared in 1887 prohibiting crab fishing by non-residents, and new laws were added in 1894 and 1896 to prohibit any person from using scrapes or dredges to catch crabs on private or public oyster grounds (Commonwealth of Virginia, 1887a,b, 1893-94, 1895-96). Until 1898, however, supervision of the fisheries remained with the governor, the auditor, and treasurer of the Commonwealth (Hooker et al., 1912).

Authority over the fisheries was granted to a newly-created Board of Fisheries in 1898, but it was limited to routine management, primarily permitting (licensing) and law enforcement (Commonwealth of Virginia, 1897-98). Additional authority was granted the Virginia Commission of Fisheries in 1919 to investigate migration, habits, and propagation of fish and shellfish (Commonwealth of Virginia, 1919; Morrissett, 1924). Authority to make regulations to conserve and promote the seafood and marine resources was not granted in Virginia until 1962; with those new powers the commission was able to regulate (with some limitations) the fisheries quickly, avoiding the time and expense of passing changes through the legislature.

The Maryland Commission of Fisheries was established in 1874 to engage in the propagation of food fishes, to make them more available, and to restore the "much deteriorated" marine and inland fisheries (Session Laws of American States and Territories, Maryland, 1874; hereafter referred to as "Session"). Some acts of the Maryland General Assembly, titled Local Public Laws, controlled crab fishing in the waters of each county throughout the 1880-1940 period and are not cited here.

Control over the seafood industry by the Maryland legislature was partially relinquished in 1906 when supervision over the oyster industry was given to the newly-created Shell Fish Commission, but no authority over the crab industry was granted (Greene et al., 1916).

The execution of all laws relating to oysters, fish, crabs, and game was delegated to the Maryland Conservation Commission in 1916 (Kemp et al., 1917a). Not until 1939 was "general supervisory power, regulation and control over certain natural resources within the bounds of tidewater" granted to a newly-created Commission of Fisheries by the legislature.

These resources included fish, crabs, terrapin, oysters, clams, and other shellfish (Session, 1939). Broad discretionary powers to meet local and temporary changes in the crab supply, and to preserve the crab fishery were not granted by the Maryland legislature until 1943 (Session, 1943).

A bill that proposed federal control of migratory fish and crustaceans in the Chesapeake Bay was proposed by a Maryland representative in 1921. Agreements on the proposed legislation were reached based on the recommendations of Churchill; enactment of the bill was considered disastrous to Virginia's industry (Bilisoly et. al., 1922). It was withdrawn following several hearings between the Commissioners of Virginia and Maryland, the federal Secretary of Commerce, and E. P. Churchill, formerly of the U. S. Bureau of Fisheries.

Gear Regulation

References to gear types, licenses, and geographic and seasonal restrictions are primarily and specifically cited for the period 1880 through 1940, but some citations for more recent years are made only for comparison, and none are cited for 1990 or later. In this text, the quantity of crabs taken by a gear is called the catch, and landings are the remaining portion after disposal of dead, damaged, and illegal crabs. This latter number was reported to federal or state management agencies. An unknown portion of the catch was sold by watermen or shippers directly to local and distant consumers, and was largely unreported.

Records of the number of any type of gear used before 1929 are incomplete. Historical data can be obtained from several sources: (1) "Fisheries Industries of the United States" and "Fisheries Statistics of the United States," 1880-1979 (1880-1960 summarized by Van Engel and Wojcik, 1965a, 1965b); (2) unpublished monthly license records of the Commission of Fisheries of Virginia and the Marine Resources Commission, (1920-79 summarized by Van Engel and Harris, 1983; 1920-60 by Van Engel and Wojcik, 1965b); (3) unpublished fiscal records of the Commission of Fisheries of Virginia (summarized by Van Engel, unpublished); (4) unpublished minutes of meetings of the Commission of Fisheries of Virginia (summarized by Van Engel, unpublished); (5) Acts of the General Assemblies of Virginia and Maryland (Commonwealth of Virginia; Session, Maryland; summarized by Van Engel and Harris, 1983, and by Van Engel and Wojcik, 1965b); (6) reports of the Board of Fisheries of Virginia and the Virginia Commission of Fisheries; and (7) annual reports of the Conservation Department of Maryland, the Department of Tidewater

Fisheries, and the Board of Natural Resources (summarized by Van Engel and Harris, 1983, and by Van Engel and Wojcik, 1965b).

For 60 years throughout the Bay, the hand-dip (ordinary) trotline was the principal gear for hard crabs, taking 69-99% of hard crab landings. Between 1907 and 1917, trotline length in Virginia increased from 600 to 900 feet (Churchill, [1917]), and may have increased from 800 to 2000 feet or more in 1916 and 1917, although the latter estimate may have included Maryland lines (Churchill, 1919a).

Dredges were used only in Virginia in winter, taking 8-17% of the hard crabs. Patent-dip trotlines, introduced before 1920 (Churchill, 1919a; Commission of Fisheries of Virginia, 1920), numbered 5% or less of the ordinary trotlines, and were used principally in Virginia (Van Engel and Harris, 1983). Patent-dips caught large quantities of crabs in October and November when crabs tend to school. Relatively small amounts of hard crabs, 0.1 - 4.6%, were caught by scrapes, dipnets, and pound nets.

Scrapes and dipnets were the principal gears for soft crabs and peelers, taking 67-99% of the landings (Van Engel and Wojcik, 1965a); 0.1 - 17% were taken by trotlines, seines and pound nets.

Licenses and Geographic Restrictions

The first Virginia license and fee was required in 1898 for using scrapes (Commonwealth of Virginia, 1897-98). Two years later, scrapes, nets, and other like devices were included in a general license and fee (Commonwealth of Virginia, 1899-1900). Despite the minimal licensing requirement, the annual increase in crabbers' licenses was small and irregular over the next 10 years (Tables 3-4).

Little is known of the distribution and intensity of fishing effort in Virginia before 1910. Lynnhaven River and its tributaries were closed to crabbing from 1 September to 15 November 1901, but the restriction was repealed in 1902, then reestablished in 1904 (Commonwealth of Virginia, 1901, 1901-02, 1904). Winter dredging for hard crabs to support the hard crab canning industry began before 1903 (Bentley, 1937; Bowdoin et al., 1903; Gandy, 1928) and perhaps as early as 1900 when the general license fee was required, and when legislation permitted that crabbing grounds could be set apart and designated in the waters of the Commonwealth (Bowdoin et al., 1904; Commonwealth of Virginia, 1899-1900).

Although dredging licenses were issued in the winter of 1902-03 (Bowdoin et al., 1903), their numbers were first reported in 1904 and 1907 (Tables 3-4; Lee et al., 1907). Licenses and fees for "scrapes, nets and other like devices" for catching crabs were required in 1904 (Commonwealth of Virginia, 1904). Lee et al. (1909) estimated that the number of unlicensed gear for soft crabbing in 1908-09 was three times that of scrapes, and for hard crabbers eight times larger, not counting the thousands who engaged in hard crabbing for short periods.

Different fees for specific gears were not set in Virginia until 1910 (Table 4; Commonwealth of Virginia, 1910), and included hand trotlines, dipnets, soft crab scrapes, and the use of sail and power boats for taking hard crabs with scrapes or dredges.

From 1910 through 1915, trotline licenses were not required unless the catch was to be picked or canned, and dipnets were exempted from licensing (Commonwealth of Virginia, 1910, 1912). Absolving certain trotlines from licensing was reiterated by the Commission of Fisheries in 1911 (Commission of Fisheries of Virginia, 1911).

Dipnets for taking either soft or hard crabs, and all trotlines were added to the list of licensed gear in 1916 (Commonwealth of Virginia, 1916). Dipnets used for taking soft crabs were exempted from 1918-62 (Commonwealth of Virginia, 1918, 1962). Between 1916 and 1962, power boats over 32 feet in length were taxed at a higher rate than shorter power boats and sail boats taking hard crabs with scrapes or dredges (Commonwealth of Virginia, 1916; Van Engel and Wojcik, 1965b). Beginning in 1912, no steam or motor boat could be used to catch soft or peeler crabs, i.e., crab scrapes had to be pulled into the boat by hand (Commonwealth of Virginia, 1912).

Acts of the Maryland legislature through at least 1940 limited crabbing in the waters of a county to residents of 12 months or more who had obtained a numbered license, an early form of limited entry to a fishery (Session, 1882, 1890, 1892, 1900, 1902, 1912, 1916, 1924, 1927, 1929). Fees were rarely required until 1916.

Baltimore City residents could obtain a license to crab in the waters of Anne Arundel or Baltimore counties (Session, 1927). Licenses were not always required of all ages: boys 10 years of age and younger were exempt from 1916 through 1932. Later, from 1933 through at least 1941, licenses were required of ages 12 through 65 (Session, 1916, 1927, 1929, 1933).

Additional restrictions varied by county. Talbot County residents could not take crabs in waters over three feet deep (Session, 1882), and the use of scoops, scrapes, and trotlines was limited to residents (Session, 1900). Dorchester County residents were prohibited from using patent twine weirs, pound nets, fykes, stick-weirs, or haul seines more than 350 feet in length (Session, 1890), and only that county's residents could use a boat, canoe, or vessel to take crabs with scrapes, drags, dredges, or similar instruments in certain waters after paying a license fee (Session, 1890). Scrape licenses for taking peeler crabs were required in Dorchester County in 1902 (Roberts, 1905), and may have been required earlier. A license plus fee was required in Queen Anne's County to take hard or soft crabs for market that year (Session, 1902).

Citizens of counties separated by a river were permitted to use the river in common: for example, license fees were set for the use of trotlines in 1912 for residents of Wicomico, Dorchester, and Somerset counties to crab in the Nanticoke and Wicomico rivers, and in 1916 residents of all Maryland counties were permitted to share use of a dividing river (Session, 1912, 1916).

Beginning in 1912, anyone taking crabs in the Potomac River by any method, or engaging in the business of buying crabs for picking, canning, or shipping had to be licensed (Session, 1912). Similar legislation regarding crabbing activities in the Potomac River was enacted in Virginia in 1930 (Commonwealth of Virginia, 1930a), but applied to citizens of both Virginia and Maryland. the record suggests that similar legislation had been enacted earlier.

Numbered licenses plus a fee were required of county residents in 1916 for the use of scrapes and dipnets for soft and peeler crabs, and for the use of trotlines or any other means for hard crabs. This included sail, motor or row boat; however, dredging for crabs on natural oyster bars in the waters of Somerset County was prohibited (Session, 1916).

In 1916, licenses were required of persons, firms and corporations that picked, canned, packed, or shipped cooked hard crabs or crab meat, or sold hard or soft crabs by the crate or barrel. Persons picking and selling crabmeat for local family trade were exempt from licenses (Session, 1916; Kemp et al., 1917a).

Not until 1922 were engines on boats that were scraping or scooping crabs outlawed in Maryland (Session, 1922, 1929). However, in 1941, any kind of motor could be used on a boat or vessel when scraping or scooping for crabs in certain Maryland waters designated by their exclusion from a list of prohibited waters, no more than two scrapes could be used, and no scrape could exceed 42 inches in width (Session, 1941).

Sharing the waters of the Chesapeake Bay outside the mouth of the Patuxent River was allowed in 1929 to residents of Calvert and St. Mary's counties who had licenses to use trotlines (Session, 1929). Although residents of counties bordering the Patuxent River presumably could be licensed to use trotlines for hard crabs, in 1935 they were prohibited from taking soft shell crabs by means other than a "net or seine with handle attached" (Session, 1935): presumably the seine was equipped with poles or brails and pulled by hand.

Trends in Gear Usage

Reservation of crabbing grounds for the soft crab fishery was assured with surveys by the Maryland Shell Fish Commission in 1912 (Mitchell et al., 1912), under the authority of Section 96 of the 1906 Acts of the Maryland General Assembly (Session, 1906).

In the early 1930s, in response to the economic depression and the destruction of boats during the August 1933 storm (Conservation Department of Maryland, 1933), bay watermen resorted to the intensive use of dipnets for soft and peeler crabs for which no license and little expense were required (Table 5; Van Engel, 1962; Van Engel and Wojcik, 1965b).

The gear change was greater in Virginia, where less than 2% of the scraping boats reported in 1930 were in use in 1934, compared with 49% reported in 1934 in Maryland. In the bay, the ratio of soft and peeler landings by scrapes to that by dipnets changed from 1.75:1 in 1930 to 1:4 in 1934, then gradually increased to 2.7:1 by 1939 (Van Engel and Wojcik, 1965a).

Wire-mesh crab pots were introduced in Virginia in 1928 (Commission of Fisheries of Virginia, 1928); however, the design was flawed and few pots were used (Van Engel, 1962). A modified pot introduced in 1936 and patented in 1938 is essentially the design in use for more than the next 55 years (Commission of Fisheries of Virginia, 1937; Van Engel, 1962).

Crab pots were banned in Maryland in 1941 in the belief that many juvenile crabs were destroyed (Pearson, 1942). They were not permitted until 1943 by regulation of the Department of Tidewater Fisheries (undated) under the authority granted by the Maryland General Assembly (Session, 1943).

Crab pots have been the major fishing gear for taking hard crabs in Virginia since 1944, and in Maryland since 1956. Pots effect a catch anytime crabs are attracted to bait during any 24-hour period, and can be set in deeper waters than trotlines, although pots are less easily moved. Crab pot landings, catch, and numbers of licenses are not discussed in this text.

Trotlines are most effective in shallow waters when crabs are schooling, are widely used in spring and fall, are more often set on cool mornings, and can be easily moved to new grounds where catches may be deemed better. The chief disadvantages of trotlines are that they are illegal to set and lift after sunset and before sunrise when crabs are moving, and are less often used under the midday sun when crabs will not surface to follow the trotline bait (Andrews, 1948; Van Engel, 1962).

Geographic and seasonal differences in hard crab landings for the periods 1919-25, 1961-70, and 1971-77 demonstrate the effects of gear change (Bell and FitzGibbon, 1977, 1978, 1980; Lyles, 1963-69; Pileggi and Thompson, 1976; Power, 1963; Power and Lyles, 1964; Sette and Fiedler, 1925; Thompson, 1974, 1984; U. S. Fish and Wildlife Service, 1960-70; National Marine Fisheries Service, 1970-79; Wheeland, 1971-73, 1975; Wise and Thompson, 1977). From 1919-25, 76.6% of the Virginia annual hard crab landings was credited to trotlines and 22.8% to dredges. In

Maryland, 89.5% was credited to trotlines and none to dredges (Table 6).

Since the major portion of the Maryland annual landings was taken from June through September, a result of the short 23-week Maryland fishing season, seasonal differences between Virginia and Maryland have been described for those four months; however, estimates were also made for July and August for comparison with landings in later decades.

Landings data by months were first reported in 1960. From June through September, 26.6% of the annual Virginia landings was obtained by trotlines, compared with 62.0% in Maryland. In July and August, Virginia landed 10.4%, and Maryland landed 29.6% by trotlines (Table 6).

The preference for the relatively more efficient crab pots and the rapid replacement of many trotlines by pots in Virginia are evident from the percentages of annual and seasonal landings by the two gears from 1961-70, and the almost total replacement by pots from 1971-77 (Table 6).

Acceptance of crab pots in Maryland has been gradual but increasing. Percentages of annual landings taken in both states in June through September and July through August were substantially larger from 1961-77 than in 1919-25 (Tables 1, 6-7), and must be credited to the increased use of crab pots.

The smaller percentage of dredge fishery landings in the later period is more likely related to the proportion of the stock that migrated to the lower bay, an amount that varies annually, than to the intensity of the trotline and pot fisheries.

Seasonal Limitations

General

Legislation in Virginia and Maryland established closed seasons in specific areas or sometimes applicable state-wide or the use of specific gears in those areas. Open seasons on the use of certain gear were stipulated in Maryland in 1890, and by inference those gears were prohibited during other months of the year. Open and closed seasons on specific gears are described in greater detail in subsequent sections of this text.

Prior to 1932, no seasonal limitations had been imposed in Virginia on any gear except dredges. Occasionally, executive orders were issued by the Virginia Commission of Fisheries to clarify the Commonwealth's legislation or to offer immediate solutions to problems.

A general closure on hard crabs was ordered in 1902 in Queen Anne's County, Maryland, for November 15 through April 30, and in Talbot County for November 1 through April 30 (Session, 1902). Beginning in 1906 and until 1929, hard crab fishing in all Maryland waters was prohibited from November 1 through April 30 (Session, 1906; Session, 1929; Earle, 1930). The November closure has often been stated as permitting more adult females to migrate in the fall to the southern portion of the Chesapeake Bay where egg extrusion and the hatching of zoeae would occur the following spring and summer.

In 1929, hard crabbing in Worcester County, Maryland, was prohibited for six months, from October 1 through March 31, while the original 6-month closure, November 1 through April 30, of all other Maryland waters remained unchanged (Session, 1929; Earle, 1930). Seasonal closure in all Maryland waters except those of Worcester County was shortened to five months, December 1 through April 30, in 1933 (Session, 1933; Earle, 1934). Worcester County's 6-month closure was shortened to five months, November 1 through March 31 in 1933 (Session, 1933; Earle, 1934), and further shortened to four months, December 1 through March 31 in 1935 (Session, 1935).

Authority to prohibit the taking of hard crabs in November in all waters except those of Worcester County, after giving public notice, was granted to the Maryland Conservation Commission in 1937 (Session, 1937).

Soft and peeler crabs have always been exempted from seasonal and geographic, but not size, limitations in Virginia and Maryland; however, it is not certain whether the 1977 ban on capture of all crabs by any gear from May 15 through September 14 in the Virginia sanctuary in the southern end of the bay included a prohibition on the capture of peelers (Commonwealth of Virginia, 1977).

Trotlines

Trotlines are baited to attract crabs, and their effectiveness depends on the temperatures of rivers and bay waters; normal use was from April through October in Virginia, and May through October in Maryland. From 1919-25, trotlines were used 23 weeks in Maryland, and 35 weeks in Virginia (Sette and Fiedler, 1925).

On March 28, 1932, the Virginia Legislature prohibited the use of ordinary and patent-dip trotlines from December 1 through April 15 (Commonwealth of Virginia, 1932). This was done to eliminate a conflict between the spring trotline and winter dredge fisheries in marketing crabs that had been in existence at least since 1916 or 1917, and probably earlier (Churchill, 1919a).

Trotline fishermen explained that their best spring catches of crabs were made in April, while the dredging season could continue until April 30. Subsequently, on March 3, 1933, the Commission of Fisheries ordered that the dredge season be ended on April 15 (Commission of Fisheries of Virginia, 1933). When it was advised that a change in the length of the dredge season could not be ordered without a public hearing, a public hearing was held on April 3, 1933, on which date the Commission reversed its decision and reestablished the end of the dredge season as April 30.

General assembly legislation in 1936 eliminated reference to seasonal limitations on trotline fishing (Commonwealth of Virginia, 1936), but terminated the dredge season on March 31.

Scrapes and Dredges

In 1890, Maryland permitted the use of boats, canoes, or vessels to take crabs with scrapes, drags, dredges, or similar gear in the waters of Dorchester County from May 1 through September 1, inclusive. But in 1892 and later, the state prohibited their use in the Great Choptank River (Session, 1890, 1892, 1900).

Although in 1903 any type of dredge for taking hard crabs could be used in Virginia from October 15 through April 30 (Bowdoin et al., 1903), it is not certain when the winter crab dredging season opened. An opening date for oyster dredging had been established to conform to Maryland laws, but no separate season for crab dredging had been set.

Beginning in 1910, Virginia law specified only the months when scrapes and dredges were prohibited from taking hard crabs: 1910-21, May 1 through October 31; 1922-35, May 1 through November 30; and 1936 through at least 1985 (references not reviewed later), April 1 through November 30 (Commonwealth of Virginia, 1910-77). The number of weeks in which dredging occurred from 1907-17 is unknown, and may have been longer than between 1919-25; according to Sette and Fiedler (1925), dredging lasted only 17 weeks, from December 1 through March 31.

Since 1936, instead of designating open seasons on the use of scrapes and dredges, the Virginia legislature defined a closed season as April 1 through November 30, which commits an open season as December 1 through March 31. Seasonal closure to scrapes and dredges was applied to the waters of Chesapeake Bay, Hampton Roads, and for many years to the ocean side of Accomac and Northampton counties. The use of those gears was prohibited all year in all rivers or their estuaries, inlets or creeks, but did not apply to the taking of soft and peeler crabs (Commonwealth of Virginia, 1936). In 1944, legislation was enacted to permit the Commission of Fisheries to open any dredge season on November 16th and extend it to April 16th (Commonwealth of Virginia, 1944).

In early years, although Virginia crab dredgers were permitted to start in November, they usually did not dredge in earnest until nearly December (Churchill, 1919a). In 1916, dredging began about November 16, the earliest known date. From 1917-1922, dredging began the last week in November (Van Engel, unpublished data). Boundaries of Chesapeake Bay and Hampton Roads where dredges could be used to take hard crabs were defined by the Commission in 1937 (Commission of Fisheries of Virginia, 1937).

Scrape or dredge licenses for use on the ocean side of Accomack and Northampton counties in Virginia were seldom addressed. They were exempt from seasonal limitations by the legislature in 1936 (Commonwealth of Virginia, 1936), a policy that remains in effect. However, between December 1935 and January 1939, the Commission of Fisheries set limits on gear types (hand-drawn dredges) and seasons (December 1 through April 30, 1935-36; January 1 through March 14, 1937-38) for sections of those counties (Commission of Fisheries of Virginia, 1935, 1937). The use of scrapes and dredges had been specifically prohibited on private and natural oyster grounds in Virginia since 1894 (Commonwealth of Virginia, 1893-94). Other grounds could be set aside for crabbing (Commonwealth of Virginia, 1899-1900).

Dredging on public grounds not leased on the ocean side of Accomack and Northampton counties (other than natural oyster beds, rocks, or shoals) was not addressed until 1939, when hand-drawn dredges were permitted from January 1 through March 14 (Commission of Fisheries of Virginia, 1939).

Dredges to take hard crabs were prohibited in Maryland until 1947 when hand-drawn dredges were permitted on the ocean side of Worcester County from November 15 through March 14; crab dredging on private oyster grounds or public clamming grounds remained prohibited (Maryland Department of Chesapeake Bay Affairs, 1965).

Size Limitations on Hard Crabs

No size limits existed in Virginia until 1912 when a 3.5-inch minimum width law on hard crabs other than peelers was enacted (Commonwealth of Virginia, 1912); justification for this act was never cited by the assembly nor by commissioners. No minimum-size law existed in Maryland before 1916 (Earle, 1916).

Efforts to enact other laws relating to crabs in Virginia and Maryland were largely unsuccessful before 1916 (Earle, 1916; Kemp et al., 1917b), probably because valid biological information about crabs did not exist, and legislatures and commissions were preoccupied with oyster industry problems.

Hay and Shore (1918) suggested that the legislatures probably recognized that life history studies of the blue crab were of practical importance in management decisions, but they were too difficult to obtain. Bay-wide oyster landings had declined over 22 years from 111.3 million (M) pounds in 1890 to 66.6 M by 1912, 60% of its former level. Value declined from $7.8 M in 1891 to $4.4 M in 1912, 56% of its former level.

In contrast, crab landings increased from 3.2 M pounds in 1880 to 45.5 M by 1908 (there were no crab industry censuses between 1908 and 1915), although they were worth only about 14% of oyster landings (Radcliffe, 1922; Anderson and Power, 1955; Lyles, 1967).

Virginia approved a 5-inch minimum-width "cull law" on hard crabs other than peelers on March 22, 1916, and Maryland passed a similar law on April 11 (Commonwealth of Virginia, 1916; Session, 1916; Parsons et al., 1916, 1917; Kemp et al., 1917a, 1917b; Earle, 1918). Virginia's new law was applied state-wide. Maryland's minimum was restricted to Somerset County in the southeastern corner of the state, the center of the state's crabbing industry, but was made state-wide in 1917 (Commonwealth of Virginia, 1916; Session, 1916, 1917; Parsons et al., 1916; Kemp et al., 1917a, 1917b; Earle, 1918).

The 5-inch minimum size restriction for maximum width across the back from tip to tip of the longest lateral spines has since become entrenched in blue crab management plans in all U. S. East and Gulf Coast states.

Size Limits on Soft and Peeler Crabs

The minimum width rule on soft and peeler crabs has varied little in Virginia and Maryland. In Virginia, peeler crabs were exempted from the 3.5-inch size limit placed on hard crabs in 1912, and from the 5-inch minimum size rule on hard crabs in 1916. A 3-inch minimum size on soft crabs was set in Virginia in 1922, but was raised to 3.5 inches in 1926 (Commonwealth of Virginia, 1922, 1926).

It is inferred that the peeler minimum width should have remained at 3.0 inches since a crab that size would have produced a 3.5 inch soft crab after shedding (Earle, 1927). Peeler minimum width in Virginia was set at 3.0 inches in 1930 (Commonwealth of Virginia, 1930b).

Legislation in Maryland in 1916 made it unlawful to keep "fat, snot and green" crabs (those not peelers) in floats or in possession (Session, 1916); the next year a 3-inch minimum size law on soft and peeler crabs was enacted (Session, 1917; Earle, 1918). In 1927, the minimum size on soft crabs was raised to 3.5 inches, and keeping "buckram" crabs was prohibited (Session, 1927, 1929; Earle, 1928).

Sponge Crab Legislation, Virginia

Along with enactment of the cull laws in 1916, Virginia and Maryland established a closed season on females with extruded eggs (Commonwealth of Virginia, 1916; Parsons et al., 1916; Kemp et al., 1917a, 1917b). Legislation prohibited capturing or possessing sponge crabs in July and August in any Virginia waters and year-round in Maryland. Previously, no protection had been given sponge crabs (Commonwealth of Virginia, 1912; Earle, 1916).

Virginia has enforced a closed season on sponge crabs every year since 1916, varying between two and 12 months' duration. The original ban in all Virginia waters during July and August continued through 1921. From 1922 until 1926, Virginia closed the season from June 15 through August 31 (Commonwealth of Virginia, 1922; Pearson, 1942). Following the conservation recommendations of Sette and Fiedler (1925) (Commonwealth of Virginia, 1926), capturing and possessing sponge crabs in all waters for the entire year was prohibited in March 1926.

The 1926 ban in Virginia affording complete protection to sponge crabs was short-lived. The law was modified in 1932 to permit taking sponge crabs from April 1 through June 30 (Commonwealth of Virginia, 1932; Earle, 1932a; Pearson, 1942) although the commission could close the season after giving 15 days notice "in the interest of conservation." Presumably, sponge crab protection continued the remainder of each year since no change in that part of the 1926 law is known to have passed.

The 1932 act to permit taking sponge crabs from April 1 through June 30 was reenacted in 1934 (Commonwealth of Virginia, 1934), but deleted a provision that prohibited using a trotline, patent trotline, or similar device from December 1 to April 15. Under the authority provided by the general assembly in 1934 and 1936, the Virginia commission shortened the season for legal fishing of sponge crabs (April 1 through June 30) by one to four weeks from 1935 through 1938: no sponge crabs were to be taken after June 14, 1935; after June 23, 1936; after May 29, 1937; or after May 28, 1938 (Commission of Fisheries of Virginia, 1935, 1936, 1937, 1938). No action by the commission was reported in their 1939 or 1940 minutes, but it must be assumed that a spring open season was still in force and that a ban on sponge crabs continued for the remainder of the year.

Enforcement of the 1934 amendment to apprehend violators of the ban became difficult for the small fleet of commission boats, and the commission began patrolling the lower bay night and day in 1941 (Mapp et al., 1941), even to the "eastern end of the three mile limit" (Commission of Fisheries of Virginia, 1941a). This action was followed by an order of the Commission of Fisheries (1941a) in June 1941, establishing a sanctuary for sponge crabs from May through August in the southern end of the bay.

In July 1941, the commission amended the order to prohibit taking sponge crabs from mid-April to mid-July, further noting that the proposal would be put in the form of a bill and presented to the next session of the Virginia state legislature; however, an act was not passed by the legislature until April 1948.

Sponge Crab Legislation, Maryland

Maryland's 1916 legislation establishing the 5-inch cull law also banned the capture or possession of an "egg-bearing female crab, known as the spawn crab, sponge crab, blooming female crab, or mother crab" and "any female crab from which the egg pouch or bunion has been removed" (Session, 1916).

An amendment to the law (Session, 1916) clarified vague synonyms for "egg-bearing females" by stating that the female had to have "visible eggs" and also made it illegal to sell such females, a clarification that was repeated in later legislation (Session, 1916, 1929). Although sponge crabs were available from Virginia for two to three months each spring beginning in 1932, possession in Maryland was illegal.

In 1941, the Maryland legislature gave broad discretionary powers to the Maryland Conservation Commission for the management of the crab fisheries. Subsequently, "the catching, canning, packing, shipping, or possession of the egg-bearing female crab known as the sponge crab, spawn crab, blooming female crab, or mother crab, or the female crab from which the egg pouch or bunion has been removed," could be prohibited or permitted after reasonable notice of publication (Session, 1941).

Regulations permitting the possession and transport of sponge crabs caught outside Maryland waters were passed in early 1944 (Maryland Department of Chesapeake Bay Affairs, 1965), while crabs caught in Maryland waters were illegal.

Early Knowledge of the Life History of the Blue Crab

The biological bases of acts setting size limitations were never documented. By 1916, information on the biology and economics of the fisheries that would have been essential to sound management practices was meager, even though state commissioners and Bureau of Fisheries personnel probably knew of an extensive list of blue crab references from the U. S. East and Gulf coasts, as well as studies in progress (Barnes, 1904; Brooks, 1882, 1893; Binford, 1911; Chidester, 1911; Churchill, [1917], 1918, 1919b; Conn, 1883, 1884a, 1884b; Earle, 1916; Earll, 1887; Hay, 1905; Hay and Shore, 1918; Parsons et al., 1916; Paulmier, 1903, 1904; M. Rathbun, 1896, 1900; R. Rathbun, 1884, 1887; Roberts, 1905; H. M. Smith, 1891, 1917; S. Smith, 1873, 1879, 1887; Verrill, 1873).

From the earliest to the most recent publications, females with ova but no visible external eggs, as well as females with fertilized eggs extruded externally on the swimmeretes, have often been cumulatively referred to as "egg-bearing" females. Only the addition of the synonyms "sponge crab," "spawn crab," "blooming female," "mother crab," "cushion crab," "orange crab," "lemon crab," "busted sook," and "females with visible eggs" in publications has served to identify females with external eggs, and even some of those may be ambiguous. Hay (1905) designated a female with a triangular abdomen as "virgin" and a female with a broad abdomen (i.e., an adult female) incorrectly as "ovigerous."

References have been made to "winter dredging of 'sponge' crabs" (Vickers et al., 1921, 1922), an error if intended to refer to all the females, although in truth it is not uncommon to find an isolated female with a brown-colored sponge in any winter dredge catch. The occurrence of an out-of-season extrusion of eggs suggests that once the hormonal system initiates the release of ova and their passage through the seminal receptacles where they may be fertilized, that the sequence continues with the extrusion of eggs, even though the eggs will not hatch.

In this article, the terms "sponge crabs" or "females with extruded eggs" will designate the condition of females with visible eggs on the swimmeretes. Confusion over the reproductive condition of a female crab can be avoided by referring to the gametes in the ovary as ova instead of as eggs, and adult females not carrying sponges can be referred to as "gravid" females.

Between 1896 and 1916, various estimates were given for longevity, and of size and age at maturity and egg extrusion. Those estimates were cited from studies in progress, the literature, and correspondents. Rathbun (1896) stated that the range in width of adult females was 5-7 inches, and of adult males 6-1/4 to 7-3/8 inches. However, smaller and larger adults have been reported since then.

The duration of life was not positively known in the early 1900's, and estimated to range from about 2 or 2-1/2 years to seven years, based on reports from watermen from New York to South Carolina and some from the Gulf of Mexico coast, and assumed to be different for male and female crabs. From those early reports, it is apparent that up to that time no one had related mid-summer and fall maturity and mating with the condition of the seminal receptacles and ovaries of females in winter and the extrusion of eggs in summer and fall. The sequence of those events was not clarified until the research studies of Churchill [1917].

Early estimates of longevity were based on scanty biological knowledge, chiefly on the growth rate as the basis for the assumptions of the age at which maturity and mating occurred. Conflicting arguments were presented whether females die or possibly molt after they spawn, whether the seasonal appearance of juvenile and adult crabs in both the Maryland and Virginia portions of the Bay resulted from migration from the sea, from the southern or the northern part of the Bay, what was the rate of accumulation of fouling on the carapace, and whether all adult females caught in winter had "spawned-out" and were barren. The last assumption was the basis of the attitude of Virginia watermen that winter dredging of crabs was the "utilization of an otherwise waste product," according to Churchill [1917].

In the shortest life cycle, the sequence of events were interpreted by Hay (1905) from books, letters and interviews, but tempered by personal observations. Hay concluded that maturity and mating occurred in August and September and that extrusion occurred in the fall or early spring. Extrusion occurred as early as March 1, 1880, at Hampton, Virginia, as late as November, but usually from April through August. Most females were believed to die after spawning, i.e., before the "first winter," since large numbers of dead females without external eggs were found in the fall on the southern shore of the bay and the adjacent ocean shore beaches.

Mating was reported to also occur between early June and the "beginning of cold weather." Hay's statement that extrusion occurred shortly after mating would be accurate if referring to spring mating, which was believed a pairing with females that had not matured the previous August or September and had survived the "first winter". Since some eggs may hatch late in a year, subsequent growth late in the first year of life would be minimal, and those crabs may not mature and mate until the third spring. Crabs that mature early in the summer may spawn that same year (Churchill, 1919b), but Hard (1942) considered that although that event occurred infrequently that variation exists in timing of copulation, growth of the ovary and ovulation.

Several references to "first winter" or "one or possibly two winters" cannot be accepted at first glance, for they do not agree with more basic information given by Hay: there is no doubt that they refer to the "first winter" or later winters after becoming mature.

Hay noted that large males are common in winter and spring and are usually battered, with shells more or less encrusted with barnacles and "oysters". Current knowledge, though still incomplete, is that fouling to that degree would not occur before the third summer and winter and fourth spring.

Hay's statement that the life span would be two years for most females, dying after spawning, but perhaps a year longer for males, ignores the first year of life in the larval and early juvenile stages.

For the longest estimated life cycle, Rathbun (1896) and Paulmier (1903) placed maturity in females in the third summer and in males in the third or fourth summer, egg extrusion in the fourth summer, and longevity in both sexes at seven years. Hay and Shore (1918) concurred that maturity was attained in the third or fourth summer. Their conclusion disagrees with the earlier report of Hay (1905); however, it is not certain who wrote the 1918 report or when. Although Shore initiated the study in 1904, all of his descriptions were presumably rewritten by Hay between 1912 and 1915-16, when Volume 35 of the Bulletin of the U. S. Bureau of Fisheries was completed (Hay and Shore, 1918).

An extensive review of blue crab biology and life history by Parsons et al. (1916, 1917) was based on studies by Hay (1905) and Roberts (1905), supplemented with conversations with Chesapeake Bay watermen. Crab width at maturity was not addressed, but growth in width between 3.5 and 5.5 inches was estimated to be a little more than 1 inch at each shedding. Parsons et al. concluded that the length of the life cycle was as described by Hay (1905), but provided new information that clarified and extended the estimate of life span. They also concurred that mating usually occurred from early June through October, but the greatest abundance of mating pairs occurred in September and October.

Egg extrusion was stated to occur either shortly after mating or not until the following summer. The latter belief was supported by their comment that most females caught in the winter dredge fishery had mated but had not yet produced a sponge, and that sponge crabs appeared in the Lower Bay in early spring at a time too early to have resulted from a spring mating. Comments by Parsons et al. (1916, 1917) predated the research results of Churchill, who had not been assigned to study the blue crab of the Chesapeake by the U. S. Bureau of Fisheries until July 1916.

Churchill's unpublished manuscript [1917] and his later publications (1918, 1919b) confirmed most of the descriptions of the life history reached by Hay (1905) and Parsons et al. (1916), but defined the life span after a careful study of the sequence of life history events.

Later studies by Churchill (1919b) and Sette and Fiedler (1925) confirmed the estimates of Hay (1905) on longevity and size and age at maturity, as well as other statements of Parsons et al. (1916, 1917). Churchill, who summarized unpublished growth data of Hay (1905) and results of his own investigations, concluded that the mean width of mature females was about six inches, and that age at maturity was 13-14 months after hatching.

Sette and Fiedler (1925) reported that <0.5% of the adult females taken in the Virginia winter dredge fishery, and about 3% of the adult females taken in the Virginia and Maryland summer trotline fisheries were less than five inches wide. It is evident that Churchill ([1917], 1919b) and Sette and Fiedler (1925) had defined the characteristic life cycle of a year class, without naming it as such.

The application of the 5-inch minimum-size law to males could have been based on the need for a uniform rule for males and females; however, no documents are known to exist that expressed that need.

Indices of Fishing Success

Interpretation of trends in catch and landings of the blue crab in Chesapeake Bay requires detailed and accurate knowledge of a multitude of factors and the means to evaluate their significance: (1) laws and regulations, (2) gear types and their numbers, (3) market conditions, (4) the quality of the bottom habitat and aquatic environment, and (5) the biology and population dynamics of the blue crab, e.g., the constancy of recruitment of immature crabs to the adult fishable stock (Van Engel, 1982a, Van Engel et al., 1982). Among these, market conditions have seldom been documented and will not be addressed.

Reference to most of those factors not already given will be cited in subsequent sections; however, although nothing is known about the rates of recruitment of immature crabs to the fishable stock, the wide fluctuations in landings and catch that have occurred in the blue crab fishery deny a constancy of recruitment. Further, before we can legislate management of the fisheries, we should know how the blue crab stocks react to changes in those factors; however, research to evaluate them is just beginning.

Trends in catch or landings may be indicators of the abundance of the stock if fishing effort (the number of units of gear, their hours of deployment, and their relative efficiency) remains reasonably constant or is known to be accurate. Fishing effort data for much of the period 1880 through 1940 are either unknown or are of questionable quality, which mitigates against sensible interpretations of their effects on trends in catch or landings.

Salient features of the landings and catch reports (Tables 1-2, 7, 8a-b; Figs. 1-2) invite description and explanation. No Figure is given for 1880-1905, since landings data for only eight of the 26 years were reported, and no catch data were collected. Frequently, for later years, parallel trends in catch of hard, soft, and peeler crabs by different gears are evident. However, statistical comparisons of catch with landings are seldom possible: catch data for one or another gear have been collected every year since 1907, while landing surveys were infrequent before 1929. Further, data sets are sometimes in disagreement when both landings and catch are available.

Throughout the discussion, when reference is given to changes in population size and catch that could have been due to reproductive successes or failures, it is implied that those changes resulted from variable survival rates of the zoeae, megalopae, and juveniles from a population self-contained within the bay, a widely held concept until the 1980's.

Plankton surveys now suggest that zoeae are transported to the continental shelf, grow through successive molts there, and are transported as megalopae back to the bay, where they metamorphose to the first juvenile crab stage. However, no estimates of the percentages of any growth stage being transported out of or returned to the bay have been presented.

Factors Affecting Abundance and the Catch

From earliest times, watermen and commissioners almost unanimously believed that the future abundance of the stock and maintenance of profitable fisheries were determined by four factors that should form the bases of management: (1) that female sponge crabs should be protected; (2) that minimum size limitations should be imposed on juvenile crabs before they are recruited to the peeler, soft, and hard crab fisheries; (3) that keeping "green" crabs (those that do not have a fully formed soft shell beneath the old hard shell, or a color sign on the outer edge of the fifth leg, (the "back fin") in peeler floats was a wasteful practice and should be outlawed; and (4) keeping buckram crabs for sale with hard crabs was another wasteful practice. The long-standing disagreement between some Maryland and some Virginia watermen, administrators and legislators that the Virginia winter dredge fishery (which concentrates on adult female crabs) was counter-productive to wise management, has never been settled. Virginia maintains that the dredge fishery is economically valuable, also arguing that taking adult female crabs in winter is less taxing on a single year class of the stock than the total bay landings of adult females by trotlines (and pots since 1939) in the fall preceding the winter fishery and in the following spring.

Controversies between users of different gears over fishing sites and seasons have almost always been settled by laws or regulations.

A few physical factors of the environment, such as extreme cold winter weather, unseasonably cool and wet weather in the spring, northeasterly storms at any time, strong wind and heavy rainstorms, and the rarely occurring hurricanes and tropical storms, were recognized or assumed as adversely affecting either or both the availability (the fraction of the stock susceptible to capture) and the catchability of crabs (the fraction caught by a unit of fishing effort). A third fraction of the stock is non-vulnerable to capture when it is inaccessible to gear. Since those physical factors were uncontrollable, they were usually ignored by watermen, commissioners, legislators, and many scientists when considering management plans.

The effects of these environmental events vary from temporarily halting fishing effort, destroying fishing gear, temporarily changing habitat preferences of crabs, and causing a minor reduction in catch for several days. If habitats are permanently altered, the natural mortality rate could rise, reducing catch for several weeks or months, or even reduce the spawning stock size and the succeeding generation of crabs.

Water quality, land management practices, water use and diversion, and habitat protection were other factors considered beyond the control of fisheries managers, but those issues were never raised in the early history of the fisheries.

Storms and Hurricanes

Although all severe winter storms that occurred between 1880 and 1940 were reported by the U. S. Weather Bureau, the effects of only a few storms on crabs and crabbing were noted in Commissioners' reports (Roberts, 1905; Kemp et al., 1919; Armstrong, 1937; Duer et al., 1937; Pearson, 1942, 1948). Large numbers of small crabs were found dead in Maryland tributaries in 1917-18; dredges hauled in large numbers of dead crabs in 1917-18 and 1939-40; and low catches of soft, peeler, and hard crabs were reported in 1902, in 1936, and May 1940, following the severe storms of 1901-02, 1935-36, and 1939-40.

Strong, often gale force winds accompanying the low pressure centers that frequently occur over the southern end of the bay and on adjacent nearshore waters cause high mortality of adult females. They are swept over sandy bottoms where their shells are abraded (Van Engel, 1982b). Similar losses must have occurred when the more intense tropical storms and hurricanes passed through the region (September 17, 1878; March 1888; October 25, 1897; August 23, 1933; September 18, 1936), but reports concentrated on the physical destruction of boats, docks, and the shifting of bottoms (Conservation Department of Maryland, 1933; Daily Press, 1984).

Other effects of severe winter storms, and record or near record low temperatures, have been only occasionally reported. In some winters, large quantities of ice formed in the tributaries of the Maryland portion of the Chesapeake Bay, and floating ice sometimes occurred through the southern end of the bay, curtailing or hindering fishing effort (U. S. Weather Bureau, 1901, 1912, 1917, 1918, 1922, 1934, 1936, 1939, 1940, 1959).

Other unusual weather conditions in the Chesapeake Bay not found in reports of the U. S. Weather Bureau (1897-1939) were provided by William Cronin (Environmental Protection Agency (EPA), 1983): severe hurricanes in 1881, 1882, 1886, 1887, 1894, 1897, 1902, and 1928; a tropical storm in 1902; and a tornado in 1926.

Temperature/Salinity/Dissolved Oxygen

Characteristics of cold waves that affect crabs have not been studied. A minimum temperature, a range of low temperatures and/or their duration, and whether cold acts independently or synergically with other factors such as fresh water flows, salinity, and dissolved oxygen, have been suggested but not determined. It has been speculated that crabs normally remaining in deep waters in early winter would move to shallower waters during an early season warm spell and be killed by one of the frequently occurring February freezes (Conservation Department of Maryland, 1931).

After mating during the final (terminal) molt, which usually occurs in the fall, adult females migrate from lower to higher salinity. Migration to higher salinity is of survival value to the species, for it places the female in an environment favorable to the extrusion and hatching of the eggs the following summer, and the subsequent growth and survival of zoeae and megalopae. From this evidence of migration (and supporting evidence from studies of osmoregulation in blue crabs in which adult females were shown to be less efficient osmoregulators in lower salinity), it was concluded that adult females do not tolerate low temperatures at low salinity (Tan and Van Engel, 1966; Tagatz, 1971). This is consistent with the observation that after a severe winter storm, deaths of adult females increase from the southern, more saline portion of the Bay, to the Maryland-Virginia border, where the salinity averages 15 ppt (Van Engel, 1982a).

The temperature/salinity factor may not be the only one involved in those winter mortalities. Studies of nutrients and dissolved oxygen (DO) in the Bay and its tributaries were seldom carried out before the late 1930s (EPA, 1983). Levels of these chemicals as indicators of trends in water quality have been reviewed by the EPA.

DO saturation concentrations decrease with increases in salinity and temperature; DO is added to near surface layers by photosynthesis, removed or consumed by biological processes, transported by horizontal and vertical advection, increased through vertical mixing by winds at any time of the year (particularly in winter), and decreased by freshwater input that decreases the mixing rate (Carpenter and Cargo, 1957; Environmental Protection Agency, 1983). Areas of the Bay where low DO (0.7 mg L^{-1}) occurs at depths greater than 30 to 35 feet have increased since 1950. Although the deficiency of oxygen in the Bay from the Patapsco River, Maryland, south to the vicinity of Reedville, Virginia, has increased in duration and intensity at depths from the bottom to the halocline (U. S. Environmental Protection Agency, 1983), anoxic conditions should be minimal in winter when the thermal resistance to mixture is low and the overturn of the water column is complete. Anoxic conditions prior to 1941 have not been reported, to my knowledge.

Surface water temperature (SWT) at or below freezing was observed at either or both Baltimore and Windmill Point in January 1884, January 1893, February 1895, February 1902, February 1904, and January through February 1918 (Table 9; U.S. Coast and Geodetic Survey (USC&GS), 1955; Bumpus, 1957). Although cold waves seldom penetrated the southern region of the Bay, record freezing air temperatures accompanying state lows were usually reported at Norfolk, Virginia (U. S. Weather Bureau, 1959).

Pearson (1948) found no "apparent" (sic) correlation between mean air temperatures in the Bay from January to March and fluctuations in annual landings between 1930 and 1944. He concluded that most fluctuations in landings resulted from causes other than occasional severe winter weather. While winter storms briefly curtailed fishing effort and caused mortality more evident among adult female crabs than males, there is no evidence in the first 46 years of the fisheries that they had any lasting effect on the stock.

According to many watermen, the opening of the spring peeler fisheries occurs during the full moon after the third week in April at about the time when SWT may reach 60°F (roughly 16°C); however, this varies from late April to early May. Mean monthly air temperature statewide for May in Virginia from 1891 through 1940 averaged 64.1°F (17.8°C), and only in 1917, 1920, and 1925 was the May mean lower than 60°F, with deficits > -4.1°F (-1.8°C) (Table 10; U. S. Weather Bureau, 1940).

In Maryland, the state air mean for May through 1940 was 62.6°F (17°C), but temperatures below 60°F, with deficits > -2.6°F (> -1.0°C), were reported for May 1907, 1917, 1920, 1924, 1925, and 1935. In Virginia, freezing air temperatures occurred at least one day in May during every year except 1892 and 1933, and in Maryland, one day in every year except 1933.

Water temperatures, rather than air, would more accurately describe conditions at Bay fishing sites, except when depressed by recent cold fresh water flows. Monthly mean SWT at several locations in the Chesapeake Bay recorded as early as 1873 were summarized by Bumpus (1957), and beginning in 1914 by the USC&G Survey (1955).

May SWT means at Windmill Point at the mouth of the Rappahannock River were lower than 60°F (16°C) six times in the 41 years 1882-1922, and once at Baltimore in the 26 years 1914-1940 (Table 9). Projections from those surface observations to temperatures at depth can be made from observations at 0, 10, 20, 30, 40 and 60 feet that were made by the Chesapeake Bay Institute of The Johns Hopkins University (Stroup and Lynn, 1963). On three Chesapeake Bay cruises (May 20-25, 1950; April 22-May 13, 1958; April 27-May 17, 1960) and on part of 24 cruises from July 1, 1949 through August 1, 1961), the surface temperature ranged from 55.4-62.6°F (13-17°C), and at 10 feet was either the same or 1.8-2.6°F (1°C) lower at both Baltimore and Windmill Point.

Unseasonably cool and wet weather in the first 10 days of April 1931, a condition not mentioned as unusual that year by the U. S. Weather Bureau, was reported to have retarded the development of crabs in Tangier Sound (Conservation Department of Maryland, 1931).

Leffler (1972) suggested that growth of blue crabs seems to be "decelerated" by cold water after observing that maturity is attained in 13 to 18 months in Chesapeake Bay, but less than a year in the St. Johns River, Florida. Unseasonably low SWTs in April or May would not only delay the opening of the Chesapeake Bay fisheries and retard molting and growth of juveniles and adult males, but could conceivably delay embryonic development and preparations for the extrusion of eggs. At Beaufort, North Carolina, sponge crabs with recently extruded eggs, presumably orange colored, were found in early April, while dark sponges were not found until four to six weeks later (Costlow and Bookhout, 1960). Salinity and temperature data were not provided.

While a few sponge crabs may appear in the southern end of Chesapeake Bay in late April in an extremely warm spring, intensive egg extrusion does not begin until mid-June, and sometimes as late as early July. It ceases by early September, at least for the 30-year period from 1955 to 1985 (Van Engel, pers. obs.), and may have been the condition earlier.

The temperature effect on embryonic development and hatching was observed by Churchill (1919b), Sandoz and Rogers (1944), Costlow and Bookhout (1960), Sulkin et al. (1976), and Amsler and George (1984). Hatching was estimated by Churchill (1919b) to occur in the 14 to 17 days between June 15 and July 2, with SWT in late June at 26°C (79°F).

In the studies of Sandoz and Rogers (1944), eggs held in shallow pans or pint jars of York River water at 21.6 to 29.0°C (71-84°F) at ambient salinity, or water adjusted from 0 to 33 ppt by evaporation or dilution, hatched between 12.8-30 ppt in 9 to 14 days. No eggs hatched at 14, 17, 30 or 31°C (57.2, 62.6, 86, 88°F).

Costlow and Bookhout (1960) observed hatching in shaker boxes in not more than 11 days at 22 or 25°C. Sulkin et al. (1976) attempted to induce ovarian development and hatching of eggs during the winter, starting in mid-November, by maintaining adult females in aquaria at 16°C (60°F) and 19°C (66°F) and at 30 ppt. Two adult females among a group of 10, held at 19°C (66°F), extruded eggs to the aquarium floor in the third week of January and the third week of February. The eggs were then held in reciprocating shakers at 25°C (77°F), and hatched in 15 and 21 days. No eggs were extruded from females held at 15°C.

In a later study, Amsler and George (1984) removed eggs from sponges (*in vitro*) and held them in shaker boxes. They also removed eggs with developing embryos daily from sponge crabs (*in vitro*). Zoeae hatched in 8 to 11 days at 25-26°C (77-78.8°F), temperatures which normally occur from mid-June through mid-September in the Chesapeake Bay, and they hatched in 45 days at 16°C, a temperature that normally occurs in the bay from mid-April to early May.

Maturation of the oocytes, vitellogenesis, and the development of ovarian lobes begin immediately after the terminal molt, whether or not mating has occurred (Cronin, 1942; Johnson, 1980; and Ryan, 1967, for *Portunus sanguinolentus*). In most blue crab females that mature in late summer or fall, the ovary has the shape, size, and color in winter as seen in spring (Van Engel, pers. obs.).

Three developmental stages are believed to be delayed until sometime just before ovulation: the development of special epithelial cells in the oviduct, the formation of the chorionic membrane of the mature ovum, and the opening of the proximal end of the oviduct, between the ovary and the oviduct. Epithelial secretions were proposed by Johnson (1980) to act against foreign substances in the oviduct and seminal receptacle, and to act as an antimicrobial substance; these must be available at the time the oviduct is open between the ovary and receptacle just prior to ovulation.

The accessory cells (also called nurse cells and follicle cells), which move to surround the oocytes at the pubertal molt (Cronin, 1942; Johnson, 1980), may become the chorionic membrane of the mature ovum in the blue crab, according to Johnson (1980). She suggested that comments by Ryan (1967) on *Portunus sanguinolentus* might apply to the blue crab. It is very possible that the three developmental stages are delayed in spring when SWTs are not "favorable" for egg extrusion, but no specific studies have been attempted to determine such temperature effects.

Amsler and George (1984) thought differences in development rates were likely due to a diapause (lapse in growth) in the gastrula occurring at the lower temperature, and that growth would eventually resume at the higher temperature. They based their explanation on the work of Wear (1974) on unrelated decapod crustaceans.

The occurrence of diapause in blue crab embryos at relatively low temperatures (16°C, 60°F) would have survival value since hatching would be delayed until adequate food was available for the zoeae. Also, longer retention of extruded eggs on the females would expose the eggs to predation and disease. The evolution of mechanisms to minimize extrusion of eggs at low SWTs would provide greater survival value for the species. The delay of mass egg extrusion until water temperatures reach 70°F in mid-June or later in the Chesapeake Bay, then a subsequent 10 to 14 days before hatching, and 30 days for completion of zoeal development, is consistent with the observed placement of megalopae in the lower bay by mid-August or early September.

Numerous climate variables have been compiled and examined for their possible effects on blue crab life history stages (Van Engel and Harris, 1979, 1980, 1981). Cooling degree days (CDD) (air temperatures >18.3°C, 65°F) in May at Norfolk, Virginia, in the year of the hatch, Delaware Bay meridional wind stress in January following the year of the hatch, and the log transformation of the York River juvenile crab catch per tow from September in the year of the hatch through August of the following year were variables in a multiple correlation analysis which explained 86% (r^2) of the variation in Biological Year (September in the year after the hatch through August the next year) commercial bay hard crab landings from 1964 through 1975 (Van Engel and Harris, 1979, 1980; Van Engel, 1987).

Since May CDD had the highest single correlation with Biological Year landings ($r^2 = 59\%$) of all variables tested, and was the only one of the three variables available for analysis for the present study, estimates of the CDD were calculated as the sum of the departures of the mean daily air temperatures from 65°F for May at Norfolk, Virginia, for 1897-1939 (U. S. Weather Bureau, 1897-1939). They are presented with the departures of Virginia and Maryland mean May air temperatures and precipitation from the long term May means (U. S. Weather Bureau, 1940) (Table 10).

Not surprisingly, since CDD and SWT are estimates of the water quality, there is a high level of correspondence between Norfolk CDD (Table 10) and SWTs (Table 9), although a closer correspondence exists between Norfolk and Windmill Point than with Baltimore. The absence of catch and/or landings data for much of the early history of the blue crab fisheries prevents analyses of the statistical relationships with abiotic factors of the environment. However, the long series of CDD (Table 10) and of SWT (Table 9) will be used in the discussion of possible effects of those variables on the success of year classes.

Since the number of CDD in May in the year of the hatch was one of the variables that correlated highly with Biological Year commercial crab landings, it is proposed that spring warm SWT encourages early development of the ovary and could be an early indicator of the strength of the new year class. In contrast, since cool spring temperatures inhibit early movement, feeding, and growth of juveniles of the previous year's hatch, the start of the spring trotline fishery is delayed, but previously established abundance is not affected.

A close correspondence between CDD and SWTs has already been mentioned. Examination of tabled values of CDD, SWT, and indices of catchability suggests that large CDD in May along with high SWTs relate closely to successful fishing the same year, but are not predictors of strength of the year class that will support the fishery one year later.

Rainfall/River Discharge

Effects of rainfall on land vary with the ground cover and soil type. While it is presumed that most water is added to deep aquifers that do not reach Bay water, urbanization and the concomitant loss of farms and forests result in less water reaching deep aquifers and more feeding into rivers. Additionally, urban and industrial needs for water may result in more and larger impoundments, redistributing the water not only to other river systems or to other parts of the same river, but leveling off extreme flows.

Excessive rainfall washes chemicals and organic matter from parking lots and farm land and flushes sewer lines into small streams and creeks, resulting in rapid bacterial decomposition of such substances, the depletion of oxygen, and contamination of Bay waters by non-oxidized chemicals. Rainfall on the Bay waters is usually insufficient to modify salinity. Seasonal precipitation, particularly July through October and March through May, is closely associated with seasonal river discharge rather than total precipitation deficit during the water year, i.e., from October 1 through September 30 (Tables 11-13).

Excessive or deficient river runoff was never mentioned by federal or state scientists or commissioners as affecting the catch between 1880 and 1940. Nevertheless, it must be obvious that both short-term and long-term changes in the salinity regime of the Bay must require physiological responses in many Bay species. In blue crabs, changes could affect reproductive and growth rates, distribution of the stock, and rates of availability and catchability.

The main water supply to the Bay is runoff from the Susquehanna River, with a mean monthly discharge during the water year of 34,430 cubic feet per second (cfs) between 1890 and 1950, recorded at Harrisburg, Pennsylvania. The Susque-hanna is the source of over 85% of the fresh water to the bay above the mouth of the Potomac River (Chesapeake Bay Research Council, 1973). Runoff from the Potomac River is second in volume, with a mean monthly discharge at Point of Rocks, Maryland, of 9,279 cfs from 1895 to 1950. A lesser amount is discharged from the James River at 7,212 cfs, recorded at Cartersville, Virginia, from 1898 to 1950 (U. S. Geological Survey, 1958, 1960).

Inflow to the Bay from these systems as a percentage of contribution from all river basins was estimated by Wells et al. (1929) at 47%, 17% and 9%, respectively. As urbanization and impoundment construction increases, contributions from those rivers will increase.

Although the mean monthly discharges from the Susquehanna and Potomac rivers differ, they were synchronized in 35 out of 50 years, e.g., low flow from both the Susquehanna and the Potomac occurred in each of those 35 years. Also, the Potomac and James river discharges were similar though not equal in volume, and were synchronized in 30 out of 46 years.

River Discharge/Nutrients/Sediments/Salinity

Deviations from the long-term means of streamflow could alter some chemical and physical characteristics of the aquatic and bottom environments such as salinity, temperature, dissolved oxygen and suspended sediments, including organics, close to or at some distance from the outfall, depending on the volume of the flow.

River discharges, shore erosion, primary productivity, and landward transport from the ocean are the principle sources of sediments (Maynard Nichols, pers. comm.). Sediments may also be transported by channel dredging and spoil disposal. The accumulation of sediments can affect several physical conditions, such as circulation patterns, salinity, dissolved oxygen, and temperature distribution, all of which have biological effects.

Nutrients in river discharges would affect the growth of heterotrophic bacteria and phytoplankters. Those alterations in the environment may affect some or all of the crab life history stages in their selection of habitat sites and food sources, which in turn could lead to changes in rates of reproduction, growth, mortality, or all three.

Discharge less than the cumulative long-term mean flow from July through October raises the salinity of more acreage in the Lower Bay, affecting blue crabs by: (1) reducing, though not necessarily eliminating, the transport of zoeae to continental shelf waters during ebb tides, thus retaining a larger than usual percentage of zoeae in the Bay; (2) providing more foraging space which could contain a larger supply of phytoplankton, permitting above normal rates of growth and survival of zoeae; (3) reducing the quantity of nutrients that normally accompany river discharge, and thus slowing phytoplankton production. To some degree, the first scenario would minimize the hazardous and unpredictable mechanisms for return of megalopae from the continental shelf to the bay in the fall.

If throughout the summer and early fall there was a reversal to discharge greater than the cumulative long-term mean in volumes up to extreme flow, the acreage of high salinity in the lower bay would be reduced. Conceivably, but without biological or statistical confirmation, more sponge crabs would seek the higher salinity waters at the mouth of the bay and on the continental shelf, where hatching of eggs and dispersal of zoeae would occur. Continued large discharge at the mouth of the Bay would lead to the dispersal of zoeae farther south and east of the bay. Nothing is known of the fate of zoeae or megalopae in such situations, or what percentage of them could be transported back to the Chesapeake Bay. Nutrient input to the Bay and adjacent continental shelf waters would increase with greater discharge and encourage heterotrophic bacteria and phytoplankton production, as observed by Zubkoff and Warinner (1973) following Tropical Storm Agnes in June 1972.

In winter and spring, March through May, flow less than the long-term mean raises the salinity of tributaries and the Upper Bay and forces juvenile crabs to migrate farther upstream to seek an environment to which they can physiologically adapt. Their ultimate destination may offer less physical space and foraging capacity than would be found downstream under a normal salinity regime. The consequences would be increased intraspecific competition for food and space and increased potential for starvation and cannibalism, resulting in higher mortality rates. How low the discharge must fall in winter and spring (i.e., less than the mean, equal to, or slightly greater than the mean) to produce this situation is unknown.

Low flow season from the Susquehanna, Potomac, and James rivers is described as July through October; the succeeding high flow period is from March through May (Tables 12-13). Average monthly means for the low and high flow seasons are marked minus (-) when the flow is less than (<) the long term mean, and plus (+) when the flow is larger than (>) the long term mean (Table 12).

Synchronism of the seasonal means differs from that of mean monthly discharge volumes referred to earlier. Seasonal low flow was synchronized in the Susquehanna and Potomac in 26 of 50 years, in the Susquehanna and James in 19 of 46 years, and in the Potomac and James in 22 of 46 years. High flows were synchronized in the Susquehanna and Potomac in 22 of 50 years, in the Susquehanna and James in 13 of 46 years, and in the Potomac and James in 18 of 46 years.

Whether June should be included in the months of summer low flow is barely debatable on either biological or physical grounds. When June discharge was added to that of July through October for each of the rivers, the discharge showed only a minimal increase or decrease in the mean (or the reverse) in approximately 5% of the years studied. Selection of discharge rates from March through May may be too late to portray the volume of flow in fall and winter in the Lower Bay, since juveniles arrive in the nursery grounds of the tributaries early in September. However, the choice of March to May might more accurately define the occurrence of the most favorable environment for blue crab growth in the Upper Bay, since migrants 10-60 mm width were rarely found north of the Potomac River in the fall of the year of the hatch and did not usually occur in Maryland in large numbers until early spring. The close relationship between seasonal rainfall and river discharge suggests that the selection of July through October, and March through May were better than other data sets.

Whether any particular variation of the water-supply cycle affects or determines the strength of a blue crab year class or affects distribution and catchability has been considered only since the early 1940s (Van Engel, 1947; Pearson, 1948). While Pearson (1948) acknowledged that fluctuations in salinity in the Virginia portion of the Bay may play a significant role in the survival of zoeae, he chose to search for the highest coefficients of correlation between the mean daily discharge for each month from the Susquehanna River (presumably recorded at Harrisburg), the Potomac recorded at Point of Rocks, and at Cartersville on the James River, and indices of fishing success of adult crabs one and one-half years later which were obtained from records of the winter dredge fishery.

The largest negative correlations between discharge recorded at Cartersville on the James River, 1930-1944, and indices of abundance from 1931-32 to 1945-46 were obtained for June, August, and May in decreasing order. Pearson selected May and June for further analysis with dredge catch because he believed they were months of heavy spawning; he obtained a correlation (r) of -0.756. Selection of discharge rates for May and June was unfortunate, based on his erroneous belief that heavy spawning occurred in those months. That intensity does not usually occur before mid-June and is more likely achieved in July and August.

Mean daily discharges reported from the Point of Rocks on the Potomac for May and June were also more highly correlated than other months with the dredge indices ($r = -0.528$), but discharges from the Susquehanna River were not correlated with catch (Pearson, 1948).

Pearson's scatter diagram and Table (his Fig. 6 and Table 16) of the relationship between the James River discharge data and of fishing success from 1930-1944 indicates that the high negative correlation depends on four data points, the two representing high fishing successes at low river discharges in 1930 and 1941, and two for low successes at high discharge in 1940 and 1942. A regression of the remaining eleven data points would be an almost vertical line with $r = 0$, which suggests the occurrence of innumerable other environmental variables or physical factors that might affect either yearclass strength, the winter distribution of crabs within the Lower Bay, or estimates of the mean daily discharge or relative abundance from the dredge catch. For additional emphasis, Pearson added that the large mean daily discharges from the James River for May through August 1919, 1924, and 1940 preceded minimum commercial yields for 1920, 1925, and 1941 (his Table 1).

Inferences about the effects of specific volumes of fresh-water runoff have come primarily from two sources: the salinity/temperature requirements for successful hatching and survival of zoeae and megalopae (Sandoz and Rogers, 1944; Newcombe, 1945; Costlow and Bookhout, 1959; Costlow, 1967; Amsler and George, 1984), and from monthly surveys of the abundance and distribution of juvenile crabs in the York River system, conducted annually since 1956.

In the latter case, more juveniles were found farther up the system in dry years than were collected in years of large fresh-water runoff (Van Engel and Wojcik, 1957). This may be interpreted as a positive physiological response to a particular salinity environment.

Further suggestion of an effect of the Bay's water supply cycle on the stock biomass is that the geographical distribution of the various life history stages of the blue crab within the Bay varies seasonally with the Bay's water supply cycle (Fig. 1). Egg extrusion, hatching, and zoeal development occur in the southern end of the Bay in mid-summer when the mean river discharges are low and the Bay salinity is relatively high. Juvenile migration into the nursery zones of the tributaries and the upper Chesapeake Bay occurs in the fall as river discharge volume increases, and juvenile development becomes more rapid in the spring when mean river discharges peak. Development to the adult stage occurs in the brackish river and Bay waters in mid-summer when mean river discharges are low, and mated females migrate to the southern end of the Bay in the fall as mean river discharges become higher (Fig. 1).

The influence of the water supply cycle on yearclass strength is less certain and not fully understood. While some zoeae are transported on ebb tides to the adjacent continental shelf waters, the percentage transported out of the Bay is not known and may range widely, probably strongly affected by the discharge volume. Return transport to the Bay depends on some still undetermined factors, such as seasonal atmospheric events.

Percentages returning, probably as megalopae, are unknown. The percentage would depend on factors of the shelf aquatic environment that affect survival and distribution. Megalopae subsequently metamorphose within the bay and its tributaries to juvenile stages, most of which are not seen until late August or early September, after which juveniles continue their migration to lower salinity regions.

Certainly, the adaptation of blue crab stock to the water-supply cycle led to the success of the stock in the Chesapeake Bay. Similar relationships between the various life history stages and their movements between fresh and salt water regions are known for all blue crab stocks on the Atlantic and Gulf coasts.

Monthly cumulative streamflow entering the Chesapeake Bay, reported from gauging stations in Pennsylvania, Maryland, and Virginia, is lowest from July through October and peaks in March, April, and May (Fig. 1) (Chesapeake Bay Research Council, 1973, Fig. 1.5; U. S. Geological Survey, 1991). Normal cumulative low flow from July through October provides a high salinity level in the lower bay favorable to the hatching of blue crab eggs and the growth and survival of zoeae, permitting the transport of some zoeae to the continental shelf, and possibly the retention of some of those early stages.

Increases in cumulative river flow in mid-fall that peak the next year from March through May provide a low and mid-level salinity feeding ground in the upper portions of the estuaries and the Bay, aptly described as nursery areas, for growth and survival of the blue crab and many other species (Van Engel and Wojcik, 1957; Cronin et al., 1970). Successes in reproduction, growth, and distribution ensure production of a large year class.

Water Supply Cycle/Blue Crab Life History Stages

Whether any statistical relationship exists between the water-supply cycle and the seasonal cycle of blue crab life history stages, i.e., that variations in the inflow effect a response in the blue crab population, for the period 1880 to 1940, may not be a reasonable expectation, considering the absence or scarcity of high quality landings and/or catch data.

Further, it is assumed that in years of average discharge each river has its primary effect on the aquatic environment, and therefore, the plant and animal communities, nearest the outfall. The geographic extent of effects would vary, since the discharge rates of the Susquehanna, Potomac and James rivers differ considerably, in a declining order. In average years, numerous other biotic and abiotic variables acting individually or in combination, such as seasonal changes in CDD, SWT, air temperature, rainfall, disease and predation, for example, would affect the communities. The variety of changing variables could cancel individual effects and result in medium-sized standing crop.

Extreme environmental conditions, occurring especially at critical times in the development of one or more of the life history stages of the blue crab, could have either positive or negative effects on stock survival. Notable events such as the James River high discharges of May and June 1930 and 1941, and the low discharges of 1940 and 1942, were followed by large and small winter dredge indices of catchability, already acknowledged by Pearson (1948). Tropical storms of 1936 and 1972 were followed by smaller blue crab harvests, while the droughts of 1980 and 1985 were followed by large harvests. Consequently, later discussion considers profound positive or negative effects of the discharge rates from the three rivers on each year class of crabs, or conflicting opinions on which river discharge has the most effect on a year class.

Caution must also be observed in the handling of river discharge data: the separation of lows less than or greater than the means as indicators of favorable or unfavorable environments for particular life history stages is convenient. In cause and effect relationships, extremes in causal variables are more likely to be highly correlated with the extremes in the effect variables, while values selected from a narrow range around any mean are more likely randomly associated and the relationship described with small, nonsignificant coefficients of determination.

Four combinations of discharge in summer and spring are recorded (Table 13). Subjectively, low summer flow seems a more critical requirement than high spring flow for successful yearclass development, since hatching and growth of zoeae and megalopae occur in the saltier, southern end of the Bay where waters from all the rivers converge.

On the other hand, since the juveniles are found in the low salinity portions of all the rivers and in the Upper Bay, degree or quality of environmental support of juveniles could vary widely between rivers. Extreme deviations from the long-term mean flow, very small or very large, would likely have the most profound effects on the chemical and physical characteristics of the Bay water and bottom. Intermediate flow would moderate variables such as salinity, dissolved oxygen, nutrient input, and suspended sediment. However, attempts to pair minimum and maximum discharge rates with catch indices have been unsuccessful so far.

While river discharge may be critical to the development of a year class, its role cannot be considered the most important factor in determining yearclass strength. That role ignores the mechanisms (not considered until the late 1970s and early 1980s) for transport of megalopae from the continental shelf back to the Bay in the fall (Van Engel and Harris, 1979, 1980).

Dams/Floods/Chesapeake-Delaware Canal/ Sediments

Prior to 1940, structural alterations in the river basins may have changed the relative contribution of each tributary to the Bay's water supply cycle. Numerous small dams on tributaries had been constructed in Virginia, Maryland, and Pennsylvania for water supply, recreation, mills, or hydroelectric power, and most dams and their reservoirs were able to completely regulate flow (Tice, 1968). Because diversion of water for consumption either within or outside a basin was minimal, none of the dams is expected to have had an appreciable effect on total discharge or salinity of the Bay, although diversions to other rivers would have altered individual river output.

Structural changes were made from 1910 through 1938 on the Susquehanna River near its mouth, and on the Chesapeake and Delaware Canal in the northeast corner of Chesapeake Bay, a short distance from the mouth of the Susquehanna. Whether those changes would have affected the physical and chemical environment of the Upper Bay, creating a more or less favorable environment for development of juvenile crab stages is speculative, since environmental data from that part of the Upper Bay is sparse or unknown for periods before or soon after.

Three dams were constructed on the Susquehanna as hydroelectric plant sites: the Holtwood dam in operation in 1910, 40 km above the river mouth; the Conowingo, begun in March 1926 and placed in operation in March 1928, 16 km above the mouth; and the Safe Harbor dam in operation in 1932, 51 km above the mouth. Those plants were best described as "run-of-river" or "peaking power plants," with no appreciable water storage and an output depending on river flow conditions. They normally discharged from 0800 to 1800 hrs during the week, but discharged none on Saturday or Sunday (Pers. Comm., Richard St. Pierre, U. S Fish. Wildl. Serv., Susquehanna River Coordinator).

Significant amounts of coarse gravel and sand must have been transported in all the tributaries of the Bay and suspended sediments deposited in the tributary estuaries and in the Bay in the last 150 years. Sediment transport from rivers was undoubtedly larger before dams were constructed, and the largest amounts were carried during floods, when river output and the concentration of sediment were highest. Coarse sediment and some of the suspended sediment were trapped behind each dam when it was completed, while most of the suspended clays and silts were transported seaward and accumulate in the upper portion of the tributary estuaries, close to the inner salt limit during high river inflow. Yet little in known about sediments deposited in most of the floods whose magnitudes and frequencies have been recorded (Speer and Gamble, 1964; Tice, 1968).

While sediment transport and it deposition may have transformed the bay bottom, substantially in some cases, it is not known whether habitat modification, turbidity increases, and the introduction of contaminants were enough in either normal or flood discharges in the past to affect any biological communities. Concerns about the potential or real effects on communities were not addressed until the early 1960's, among them several studies on channel dredging and spoil disposal, which will be reviewed in a later section.

The largest sediment discharge to the Chesapeake Bay comes from the Susquehanna. Most of that river's suspended clay and silt accumulates in the upper 20-30 km of the bay during average discharge (Chesapeake Bay Research Council, 1973; Schubel and Hirschberg, 1978).

At least five episodic floods of the Susquehanna River have occurred in the last 150 years (Tice, 1968). Sediment discharges from two of them, March 17-19, 1936, and Tropical Storm Agnes, June 19-23, 1972, were estimated to be accountable for about one-half the sediment deposited in the upper Bay since 1900 (Schubel and Hirschberg, 1978). They found that the sediment accumulation from the 1936 flood was 30 cm, twice that from Tropical Storm Agnes, and estimated that the 1936 flood was the larger, based on the accumulation of flood waters extending over several days. Interestingly, sediment plumes 80 to 120 km from the mouth of the Susquehanna were recorded in the first week following Agnes and 80 km south during July (Chesapeake Bay Research Council, 1973).

Numerous Susquehanna River floods occurred between 1786 and 1900 (Tice, 1968), three of which were considered by Schubel and Hirschberg (1978) to have probably transported more sediment to the upper Chesapeake Bay than later floods, since the first of the lower river dams, the Holtwood, was not in operation until 1910.

Two other floods, one in March 1902 and another in March 1904, were not mentioned by Schubel and Hirschberg (1978), and may have transported large amounts of sediments to the Upper Chesapeake Bay. Discharges in March 1902 were the eighth largest from the Susquehanna River and the sixth largest from the Potomac River from 1786-1945 (Tice, 1968).

A hitherto unmentioned Susquehanna River flood recorded on March 8, 1904 at McCall Ferry, Pennsylvania, was either larger than or the second largest of all that occurred before 1900 (Tice, 1968). The drainage area servicing McCall Ferry was larger than that of other reporting gaging stations on the river. Strangely, few stations in the Susquehanna, Delaware or Passaic river basins recorded any discharge on March 8-9, 1904 (two reported ice jams) but one in the Susquehanna River Basin at Wilkes-Barre, Pennsylvania, reported a cubic feet per second (cfs) discharge about 90 % that of the flood of 18 March 1936, suggesting a significant flood (Tice, 1968). That flood could have transported large amounts of sediment to the Chesapeake Bay in 1904.

River discharges reported August 23-25, 1933, in the Susquehanna and Delaware river basins were relatively small (Tice, 1968), surprisingly so considering that the storm did so much physical damage in Chesapeake Bay.

Earlier comments about the frequency of synchronization of monthly river outflow from the Susquehanna, Potomac and James rivers, and of the seasonal low and high discharges, do not apply to the frequency with which episodic floods occurred. Floods listed by Speer and Gamble (1964) and Tice (1968) for the 150 year period 1786-1945 occurred with different magnitudes and frequencies in the Susquehanna, Potomac, Rappahannock, and James drainage basins, not too surprising since the four drainage basins are usually affected by different weather patterns. Particularly striking is the change from the greater frequency of floods from March to May in the northern basins, to more floods in southern than northern basins in late summer and fall. Floods occurred in one or more of the basins in every month except July. One March (1936) flood was reported simultaneously over a few days in the Susquehanna, Potomac, and James basins, one other in March (1902) in the Susquehanna and Potomac basins, once in April and June and in October (1889) in the Potomac, Rappahannock, and James basins, and one in May (1924) in the Potomac and James basins.

Twenty-five Susquehanna River (Harrisburg station) floods exceeded 300,000 cfs, range 300,000 to 1,130,000 cfs, between 1786 and 1945. All those floods occurred between October and June. Seventeen recorded from March through May, with 13 in March. Discharges from the Potomac River (Point of Rocks station), which has about one-half the drainage basin area of the Susquehanna, were significantly smaller and less frequent: only six floods occurred, range about 220,000-485,000 cfs, four occurring from March through May, one in June and one in October. From the Rappahannock River (Fredericksburg station), with about 6 % of the drainage basis area of the Susquehanna, there were only three significant floods, range 134,000-140,000 cfs, occurring in April, June, and October. Interestingly, there were few reports from any basin of flooding in August 1933. Fourteen floods were reported from the James River (Cartersville station), range 103,000-180,000 cfs, five from March through May, and nine from August through December.

Characteristics of sites in the Chesapeake Bay and its tributary estuaries where life history stages of the blue crab have been found, have been described only in general terms of salinity, temperature, and the occurrence of submerged aquatic vegetation (SAV). Watermen's knowledge of preferred blue crab habitats is the basis of their crab fishing success.

Similarities and differences in river input, sources and types of sediments and zones of deposition, and sources and containment of contaminants have been described for the Bay and its estuaries (Schubel and Carter, 1976; Nichols et al., 1991a; Nichols et al., 1991b). Such studies could provide part of the basis for defining blue crab habitats.

Channel dredging and spoil disposal in the Chesapeake Bay and its estuaries offer an opportunity to study the composition of bottom deposits, its contaminants and the benthos, the spread of the redeposition of spoil, spread of plumes of suspended sediment, turbidity, loss and recovery of biological communities in the dredged channel, and the spoil disposal site and adjacent areas. Studies have varied in the choice of dredge equipment, the site and season for the operation, and whether the chemical and physical conditions and biological community composition were surveyed pre- and post-dredging, and at a later time to determine the extent of change in the communities.

Succinctly stated, while much has been learned about the distribution and composition of the bottom sediments in the Chesapeake Bay, the principal objective of dredging and spoil disposal surveys in the Chesapeake Bay has been to determine their impact on the biological communities, particularly those organisms that would be involved in sustaining seafood species of commercial and recreational importance (Cronin et al., 1970; Nichols et al., 1990; Virginia Institute of Marine Science, 1967). Can the results of those surveys be extended to perceivable or predictable effects by transported sediments or scouring resulting from floods, excessive wave action or tides?

The Chesapeake and Delaware Canal has special interest for two reasons: (1) concerns in the late 1950's about the effects of additional enlargement through channel dredging and spoil disposal which prompted studies on the chemical and physical environment and biological communities; (2) connection between the upper Chesapeake Bay and Delaware Bay which provided potential exchange of juvenile blue crabs.

The four-lock Chesapeake and Delaware Canal completed in 1829 was converted to a sea-level, unobstructed waterway in 1927 by removing the locks and deepening and widening the channel to 14 feet and 150 feet (Cronin et al., 1976). The Canal is an extension of the Elk River, a bay tributary in the northeast corner at the head of Chesapeake Bay, and to the east enters the Delaware River at Reedy Point. Additional widening and deepening of the canal to 27 feet and 250 feet was completed in 1938.

The higher elevation of the western end ensured a net eastward transport of water, which characteristically occurred over an extended period, but was subject to short-term changes in direction and volume of flow by different meteorological conditions. Changes in the mean channel salinity in the Delaware River off the eastern end of the canal, measured at approximately quarterly intervals between November 1951 and August 1954, ranged from 0 to 8 ppt, highest from August through November, and lowest in February and May (Cronin, 1954).

Initiation of additional enlargement of the Canal and its approaches from Upper Chesapeake Bay in 1958, to 35 feet in depth and 450 feet in width, prompted concerns over the effects of dredging, and spoil disposal on the chemical and physical environment and possible effects on the distribution and abundance of biological communities.

Preliminary to modifications to the Canal, channel dredging and spoil disposal in a 20-mile portion of the Upper Chesapeake Bay, the approach to the Elk River and the Canal was initiated in late fall of 1965, a second dredge and disposal was carried out from 7 October 1966 to 11 November 1966, and a third set after 17 October 1967 to about 5 December 1967. Chemical, physical, and biological surveys were addressed from November 1965 through November 1968 (Cronin et al., 1970).

No gross effects on phytoplankton, zooplankton, fish eggs, larvae, or fish were observed, although some could not be evaluated, possibly because of movement of some of the organisms from the study site. In that study, the benthic biomass at the disposal site and in the channel decreased immediately and extensively, but less so in the area between the two sites. Recovery of biomass occurred months and up to two years later.

In 1970, when only about 80 % of the Canal enlargement had been completed, and when further concerns were expressed about the effects the modifications might have on the chemical, physical, and biological conditions in the Canal and in the Upper Chesapeake Bay, the U. S. Corps of Engineers proposed and implemented a series of studies. Pertinent hydrographic and biological studies that were contracted to other institutions were summarized by Cronin et al. (1976).

Hydrographic studies between 1969 and 1974 demonstrated changes in volume of flow in either direction and increases in salinity at the head of the Chesapeake Bay. Diversion of water through the canal was expected to alter salinity at the western end of the canal more during low discharge from the Susquehanna than during high river discharge, but the mean salinity difference would be about 2 ppt (Cronin et al., 1976).

The composition and seasonal abundance of the benthos, blue crabs, fish, and fish eggs and larvae were determined by various bottom grabs, dredges, and trawl nets, and each were reported separately, as referenced by Cronin et al. (1976), and not summarized here. Studies of the effects of dredging and spoil disposal on benthos were dismissed as probably being of relatively short duration, as indicated by previous studies. Although suspended sediment load was expected to increase as a result of a 2.5 fold increase in non-tidal flow eastward, detrimental effects on eggs and larvae of striped bass and white perch were considered unlikely.

Submerged Aquatic Vegetation/Fungus Infestation

Submerged aquatic vegetation (SAV) in the shallow waters of the Chesapeake Bay has been described as a nutrient source, a natural habitat for a dense and diverse faunal population, and a mechanism for stabilizing sediments and reducing shore erosion. Different species of vegetation occupy the range of salinities found in the Bay from fresh water to marine sites, and changes in species composition and abundance have been reported since the early 1930s (Kemp et al, 1983; Orth and Moore, 1984).

Several explanations for those changes have been offered, principally those that inhibit photosynthesis because of light reduction, and to a very much lesser extent herbicides and browsing (Kemp et al., 1983; van Montfrans et al., 1982). Two factors have been demonstrated to inhibit photosynthesis: nutrient loading from river discharges and land runoff, which promotes phytoplanktonic and epiphytic growth, and to a lesser extent, turbidity caused by suspended sediments, derived from river discharge, shore erosion, and non-tidal waves causing deposition and resuspension (Kemp et al., 1983). The primary interest here is whether SAV changes could be associated with variations in abundance of the blue crab as measured by variations in catch and/or landings.

A previously unknown parasitic fungus on blue crab eggs was first observed in the Chesapeake Bay in 1941 (Sandoz et al., 1944), and was described and named *Lagenidium callinectes* by Couch (1942). Sandoz and Rogers (1944) found a 90% hatch of uninfected eggs in a laboratory hatching study, and estimated a high hatching rate after observing large numbers of empty egg cases on sponges obtained from the southern end of the Bay.

In an intensive study, Rogers-Talbert (1948) described the range in percent infestation among sponges of different color, i.e., stage of embryonic development, the density of infestation on individual sponges, the salinity tolerance of the fungus, and the percentage of infestation in the Hampton Roads-Lynnhaven area each week between early May and late August 1944. Infestation was found predominantly among sponge crabs from the open areas and inlets of the southern end of the Bay, and rare in southern tributaries. Although embryos in all stages of development were infested, most often only the 3-mm outside layer was infested, consisting of about 25 % of all eggs, while deeper lying eggs were only occasionally infested. A higher degree of infestation was found in only about 25 % of the sponges, which led the author to state that it seemed unlikely that the fungus could be "regarded as a factor in the fluctuations of crab populations."

Landings and Gear Data

The effects of man's fishing on the blue crab stock of the Chesapeake Bay have never been fully explored. Major obstacles have been the failure to license or report the number of watermen and/or units of gear, the absence or inadequacy of measures of fishing mortality rate for the diverse types of gear, and the uncertainty of the quality of landings data, all of which are characteristic of any complex fishery.

Equality of fishing efficiency could only be addressed if information was available for each gear type, such as number of units of gear and hours of fishing. Assessment of the industry was infrequent before 1929 either because the need went unrecognized, or because state and federal agencies were unwilling or fiscally unable to address it. Comments on the supply of crabs have frequently appeared in the states' commission reports, but they must not be taken too literally since some appear to be subjective comparisons of current conditions with those only one or two years earlier, or verbatim of reports printed the previous one or two years. They are of value when indicative of trends in the catch and landings over periods when no comprehensive canvasses of the fisheries were made.

Observations on the numbers of "small" crabs that could be the source of the subsequent crop were occasionally cited. One would expect that when federal landings, commission reports on the fisheries, and independent surveys of catch were available, there would be close agreement on the relative size of the stock. This has not been the case, primarily because of the separate, uncoordinated means by which the data were obtained, and because of the persistent, uninformed effort to obtain data on a calendar year basis rather than by year class in a Biological Year.

From 1929 to 1977 (except 1943), federal agencies annually published the number of watermen engaged in the crabbing industry, the number of each gear type, boats and vessels used, and landings from each gear type. More recent data are available from the National Marine Fisheries Service (NMFS) on request. Monthly landings for Virginia and Maryland were published as Current Fisheries Statistics (CFS) from 1960-79 by the U. S. Fish and Wildlife Service and NMFS in cooperation with state agencies (U. S. Fish and Wildlife Service, 1960-70; NMFS, 1970-79). The Virginia Marine Resources Commission (VMRC) has been publishing monthly landings as Commercial Fisheries Statistics (CFS) since January 1978 (Virginia Marine Resources Commission, 1978-1992, but none more current). Maryland landings since 1979 are available from the state on request. Statistical estimates of the success of each year class have been made possible here by rearranging monthly data into Biological Year data.

Most landings and effort data for 1880-1940 have been inadequate as estimates of fishing success, which became evident when summaries and analyses of landings and effort were compiled (Van Engel, 1950; Van Engel and Harris, 1983; Van Engel and Wojcik, 1965a, 1965b). More useful measures, such as daily or weekly catch by winter dredges, trotlines, scrapes, and dipnets, had been collected by independent investigators in special studies (Van Engel, 1951, and later unpublished data; Applegate, 1983).

The frequently overlooked reports of Churchill (1917), Sette and Fiedler (1925), Pearson (1942, 1945, 1948), and Cronin (1944, 1982) presented catch data by various gears from 1906 through 1945. Catch data from December 1906 through March 1946, derived from different gears, are shown as originally reported in either pounds (or barrels), numbers daily or per week, or as indices of catchability when the latter were provided by the authors (Table 8a). All catch data were then converted to indices to compare their relative success by year class (Table 8b).

Since the construction, location of set, and season of use were strikingly different for each gear type—scrape/dip net, trotline, and dredge—it is assumed they had different catch efficiencies. The catch from each model of gear type formed the bases for comparison with catches from the same gear type in different time periods and for the calculation of indices.

Catch data and indices of catchability are listed for periods 1906-07 through 1945-46 (Tables 8a-b), and separately for the three fisheries: soft crabs and peelers taken by scrapes and dipnets (ScD, cols. 1-3, 18-19), hard crabs by trotlines (Tr, cols. 4-9, 12, 15a-d), and hard crabs by winter dredges (Dr, cols. 10-11, 13, 16-17).

Assignment of data to each time period varies with each of the fisheries, and therefore, must be viewed cautiously. It should be apparent that catch compiled on a calendar year basis consists of two year classes: a spring and early summer catch derived from an older year class, and a late summer/fall/winter and subsequent spring catch to a one-year younger year class. Complete separation of the two age groups during field monitoring surveys would be nearly impossible because growth data reveal large differences in size between individuals of the same age during the second spring and summer of life. There are two choices: either ignore age differences, or arbitrarily divide the data set by months based on general knowledge of the fishery.

While differences between spring and summer catch and indices are evident in the brief Virginia scrape series

(ScVA) listed for 1942-43 to 1945-46, they are incorrectly shown in Tables 8a-b, cols. 18-19, because of the physical problem of presentation. The indices listed in col. 18 represent May catches and should be attributed to the year classes 1940-43, not to 1941-44, while the indices in col. 19, which represent the June through September data, are properly referred to year classes 1941-44.

Recalculation of the mean indices for those five periods shows changes in decreases from 0 to 24%, and one 18% increase from the mean index shown in Table 8b. However, the magnitudes of those indices are too small to justify manipulating the table to show two different year classes as sources of the catch and indices.

Scrape/dipnet (ScD) data for the first period tabulated, 1919-20, were collected from April or May through September and consist of the 1917 and predominantly 1918 year classes. Approximate calendar year trotline (TrYr) records from May through October in Maryland, and for April through November in Virginia, are comprised of the same year classes, 1917 and 1918, as the ScD group.

Fall trotline (TrFl) data cover the last six weeks of the 1919 fishing season in Maryland and the last 13 weeks in Virginia, consisting almost wholly of the 1918 year class. Fall/spring (TrFS) data cover fall 1919 plus the first nine weeks in spring 1920 in Maryland, as well as 14 weeks in Virginia, consisting almost wholly of the 1918 year class. Dredge data (Dr) represent the catch from December 1, 1919 through March 31, 1920, and almost wholly consist of the 1918 year class.

Catch and indices of catchability (Tables 8a-b) were derived by several methods, depending on the source and composition of the data. As one example, Pearson's (1948) dredge indices (Table 8a, col. 14) were comparisons between the 14-year mean daily catch for each week of the year of record, obtained from all the vessels for which daily catches were available, and the mean daily catch of two vessels that dredged for the 14 years. The latter was designated as a "norm of seasonal availability" (mislabeled—should be "catchability,") and the ratio was adjusted by total days of fishing (Pearson, 1948, his Tables 10-11).

Understandably, no single year could be designated as a Base Year. For those gears, when only indices and no original data were reported, columns are headed Index, and the Base Year was assigned by the author (Pearson, 1948; Van Engel, 1951; Tables 8a-b, cols. 3, 14, 16-19).

Application of that method to various combinations of 14-year or 20-year norms of catchability of two vessels or all vessels, and the 14- or 20-year catch of all vessels from 1931-32 to 1944-45 or from 1931-32 to 1950-51, produced indices of catchability strikingly similar and sometimes almost identical to those found by Pearson. One set, using the 20-year norm and the 20-year catch for all boats (Van Engel, 1951) is shown in Tables 8a-b, col. 16.

The difficulty in computing the index in that manner becomes apparent if indices are computed as each new year's data become available, for it is then necessary to recalculate the "norm" and the index for each earlier year. Secondly, when the study covers a lengthy period, it may be impossible to find a group of vessels whose composition was unchanged to comprise the basis of the "norm."

Since each index is simply the ratio of the mean catch of one year to a norm, it is a relative index of catchability that can be compared with the indices of all other years. Therefore, selecting the mean daily catch of any year as the norm would result in a set of indices. Consequently, the catch of three boats operating in the winter of 1931-32 was chosen as the norm for a new set of computations using Pearson's method of analysis (Tables 8a-b, col. 17), but by necessity designating 1931-32 as the Base Year with a value of 1.00. It is apparent that the ratios of each year to a norm remain the same, but the magnitude differs by one-half when the catch of three boats operating in 1931-32 is used as a norm (Table 8b, cols. 16-17).

Similar calculations were made for Virginia spring (May) and summer (June through September) soft crab scrape catches for the period 1941-1953 (only 1941-1945 shown in Tables 8a-b, cols. 18-19), using year class 1953, catch in 1953-54, as the Base Year with a value of 0.768.

Pearson used another method of analysis for immature crabs (soft and peeler crabs) (1948, his Tables 5, 7). Instead of using the records of one or more sets of watermen to establish a single "norm of seasonal availability (catchability)," the ratios of the average daily catch by 2-week periods in each pair of successive years from 1936-44 were calculated, using logarithms for convenience. He then converted ratios to indices by comparing them to an arbitrarily chosen Base Year value of 1.00 (Tables 8a-b, col. 3).

Another method of computation was used when only annual or seasonal means of catch per day or per week was reported (Churchill, [1917]; Sette and Fiedler, 1925; Pearson, 1945, 1948; Cronin, 1944; Maryland Dept. Res. Educ., 1955). Means of successive years were used to calculate a series of ratios that were then related to a Base Year to obtain an index of relative catchability (cols. 1, 2, 4-13, 15). The value of the base year, 1.00, does not imply that all gear have the same efficiency.

Churchill ([1917], 1919b) referred to records of the daily catch of each crabber kept by a Hampton, Virginia firm from 1878, from which he extracted the mean daily catch for each week: he reported only the means for 1907 through 1917. Churchill's graph for 1917 (1919b, his Fig. 1) shows a much-reduced catch from July through early September, which he first attributed to a cessation of operations by the dealer as a result of the sponge crab ban imposed in 1916.

However, an even smaller catch from mid-August through September 1910 was reported by Churchill (1919b, his Fig. 2) and by Sette and Fiedler (1925, their Fig. 8). In the graph for 1910 presented by Churchill (1919b) and by Sette and Fiedler (1925), some weeks in August and September are noticeably missing and unexplained, suggesting that data were either not obtained from dealers, or were purposely omitted by Churchill. Unfortunately, the original catch data are not available for study.

A long-lasting summer decline in the Virginia trotline catch, from mid-June through September for some years from 1919-1925, is evident from data presented by Sette and Fiedler (1925, their Table 5, Fig. 6), and a shorter season in Maryland, from early July through mid-September (their Table 4 and Fig. 5). Those authors finally concluded there was a normal seasonal decline in every year. How much, if any, of a decline in summer catch was due to the sponge crab ban cannot be determined from existing published data.

Churchill (1919b) explained that the summer decline in catch could have been caused by one of two reasons: (1) most of the crabs had been caught previously; or (2) large numbers of adult females died after spawning. Among adult females taken from the winter dredge catch between December 24, 1924 and March 26, 1925 among equal numbers examined at one to two week intervals, all had sperm in the seminal receptacles and "immature eggs," i.e., ova, in the ovaries (Sette and Fiedler, 1925).

The presence of empty egg cases on the swimmeretes of 32.6 % of the females should not be considered an estimate of the total that had spawned the previous summer, since empty egg cases disintegrate over winter. The number with empty egg cases reported by Sette and Fiedler seems excessively high, based on more recent studies with larger sample numbers.

Over many years, I have frequently examined females caught in the winter dredge fishery. These examinations indicated that only an average of 5% of the females had spawned previously (between January 1953 and March 1955, only 2.6% of adult females had spawned each of the previous summers, Van Engel, unpubl. data). Large, red nemertean worms, *Carcinonemertes carcinophila*, on adult female blue crab gills are better indicators of spawning history (Van Engel and Ladd, 1954).

Other explanations for the summer slump in catch are equally defensible. Females may move to inaccessible areas that are not fished by trotlines as intensively in summer as they are in spring and fall. As well, trotlines fished in summer are set only a few hours a day, primarily in the morning and late afternoon, since crabs drop off the lines at midday to avoid direct, overhead sunlight. Reduction in trotline catch would also be expected any time some adult females move to deeper waters of the Bay and others move to the ocean and either die or return to the Bay as "sea-run" crabs the following spring (Van Engel, 1958).

Reductions in late summer and fall catch have not, however, occurred in recent years, despite the existence of a summer sanctuary in the southern end of the Bay. Most crabs hatched the previous year mature between late July and early October, and the Virginia crab pot catch has been highest in July and August. Pots were invented in the late 1920s, but were not introduced until the late 1930s. Not extensively used until the early 1940s, they are fished 24 hours a day and are most effective between sunset and sunrise (Van Engel, 1962). The extraordinary effectiveness of crab pots, when added to the catch by trotlines, presents an altogether different picture of the catchability of crabs throughout the year, as demonstrated in Fig. 2, showing the monthly percentage of annual landings from 1960-87.

Almost 50% of landings in Maryland have occurred in July and August, and 25% in Virginia. A significant difference in the seasonal hard crab catch distributions in Maryland and Virginia reported by Churchill [1917], Sette and Fiedler (1925), Cronin (1982), and those of 1960-1987, invites speculation for cause. Either the seasonal differences in catch and landings occurring by state and gear between 1919 and 1987 demonstrate increased fishing intensity that accompanying gear changes needed to satisfy market demands, or there has been a significant change in the seasonal cycle of abundance as a response to environmental changes, or both.

The mean weekly bi-state trotline catch from 1919-25 (Tables 8a-b, col. 5) when reported by Sette and Fiedler (1925, their Table 1) probably did not exclude July and August, for the mean catch for each year is almost identical to the sums of the weeks shown in their Tables 4-5, in which July and August's catches are given. Since the bi-state catch actually consisted of two year classes, an early spring older year class and a fall younger one, assignment of an index of catchability to the bi-state catch is inaccurate.

Catch and indices of the Maryland and Virginia fall trotline catch for 1919-24 (Tables 8a-b, cols. 7a-b) were computed from data listed in Sette and Fiedler's Tables 4-5, covering six weeks in Maryland and 13 weeks in Virginia. The fall/spring catch and indices (cols. 8, 9) are weighted means estimated from two successive calendar years from Sette and Fiedler's Tables 4-5. The fall catches are summarized as stated above, and the following spring catches are summarized over nine weeks in May in Maryland and 14 weeks in Virginia. The fall and fall/spring trotline catches would naturally exclude the summer months July and August.

Virginia's December through March dredge boat catches (col. 10), reported by Churchill ([1917], 1919b) and restated by Sette and Fiedler (1925) for the year ending, have been rearranged in Tables 8a-b for year beginning, so that the year class of origin can be shown. The winter catch should be derived almost wholly (95%) from the same year class as the scrape/dipnet, fall trotline, and fall/spring trotline catches.

Winter dredge boat data for 1907-11 and 1914-17 were extracted by Churchill ([1917], 1919b) from records of the Hampton, Virginia firm that provided the trotline data, and probably covered the 17 weeks from December 1 through March 31. Although the open season for dredging extended from November 1 through April 30 in most of the early years, normally boats did not dredge before December 1, or after March 31.

Sette and Fiedler (1925) also reported the dredge catch for winters of 1916-17 through 1924-25 (col. 11). Indices for later years, 1925-26 through 1945-46 (cols. 14, 16), were those calculated by Pearson (1948) and Van Engel (1951).

Maryland's fall trotline data from 1925-26 through 1944-45 were originally shown by Pearson (1945, his Fig. 2) as percent deviations from a long-term mean of daily catch, 290 pounds, by Tilghman Island watermen. Data were translated into catch, and indices were calculated from a series of ratios (col. 6) as described above. Pearson's description of the catch from Maryland did not designate the months when catch was made; however, a reasonable estimate would place the period over seven weeks, from September through October.

An extensive and intensive study of trotline catches at several sites in Maryland by Cronin (1944, 1949, 1982) was derived from crabbing house records. Graphs of average daily trotline catch by Tilghman Island watermen, 1925-48 (Cronin, 1949), 1925-54 (Maryland Dept. Res. Educ., 1955), and 1925-59 (Cronin, 1982) show both seasonal and annual changes in the average daily catch.

Since Pearson's (1945) and Cronin's (1949) graphs were derived from Tilghman Island records, it would not be surprising if trends in catch from 1925-44 from both sources were similar, even though Pearson's figure presented the annual fall catch data, while Cronin's data represented the calendar year catch.

Although average catch per day or week and effort data from 1925-44 were not reported by Cronin (1949), the average daily catch per week from 1936-43 for Tilghman Island and St. Michael's, Maryland were listed separately, but without effort days. Data for the two sites combined, including effort days, were found in a manuscript of Cronin's (1944).

For reasons unexplained, average daily catch per week for 1936-43 estimated by Cronin (1944) differed from estimates of the catch that I obtained from any of Cronin's 1949 graphs. However, trends of the indices of abundance calculated for the calendar year using the fall and fall/spring data of 1936-43, and the catch/effort data from Tilghman and St. Michael's, are remarkably similar to those seen in the indices obtained from Pearson's 1945 and Cronin's 1944 data (Table 8b, cols 6, 15c-d).

Differences between annual and seasonal indices (cols. 6, 15a-b, 12) are ascribed primarily to representation of two year classes in an annual index and only one year class in a seasonal index. Fortunately, from a graph of Tilghman Island's trotline catch per unit effort, purportedly from the Maryland Department of Research and Education (1955), I was able to calculate indices of relative abundance in the same manner as indices were calculated from Pearson's graph (1945), demonstrating similar trends in the catch (Tables 8a-b, cols. 6, 12).

Pearson (1948) described another set of data, an index of catchability of adult females, or "spawners," obtained by trotline in the southern end of the Virginia portion of the bay from June 1 to September 15 of 1942-1945, which is not shown in Tables 8a-b for lack of space.

Associating the magnitude of the catch with the progeny of a particular spawning stock to the effects of either adverse or favorable environmental conditions, the effects of changes in fishing effort due to laws and regulations on gear, and seasonal or size limitations, cannot be made without a thorough understanding of the life cycle of the blue crab as it occurs in the Chesapeake Bay region.

To briefly review: zoeae hatch in the high salinity waters of the southern end of the Bay with peaks in July and August, and some or many are transported on ebb tides to the adjacent continental shelf waters. Development to the megalopal stage occurs in the Bay or the adjacent continental shelf waters through late summer and early fall, and the megalopae are transported from the shelf back to the Bay in fall. Megalopae subsequently metamorphose within the Bay and its tributaries to juvenile stages, and continue their migration into lower salinity regions of the tributaries of the southern and northern ends of the Bay.

In the year of the hatch, a maximum width of 60 mm (approximately 2.3 in) is attained by juveniles by late October, too small a size and too late in the year to enter the peeler fishery. Growth resumes the next spring in late April or early May, and legal-size peelers ($\geq$ 75 mm) enter the peeler fishery by mid-May or mid-June.

The intensive peeler fishery that begins each year in late April or by mid-May focuses on the largest peelers, which are the progeny of an older year class that hatched two years earlier; in later months it concentrates on the juveniles of the younger year class. The peeler catch substantially decreases in late August or early September after the major portion of the younger year class matures, and the fishery usually ceases by mid-October.

The catch of soft and peeler crabs after mid-summer, i.e., between June and September, in the year after hatch should reflect the strength of the youngest year class, and could be used as a predictor of the strength of the hard crab trotline and winter dredge fisheries that will occur from the succeeding fall through spring.

Unfortunately, state and federal surveys of the soft and peeler fisheries continue to be ill-devised, and grossly underestimate catch and landings. Still uncounted are the crabs held for shedding, whether green crabs or peelers, that die before they molt. These percentages range from 30 to 90% of the catch (Van Engel, pers. obs.).

The persistent canvass and reporting of hard crab fisheries on a calendar year basis fails to recognize that the catch/landings are a mixture of at least two year classes and cannot be used to estimate the strength of individual year classes. The introduction of federal monthly reports in 1960 provided the means of separating landings with a reasonable degree of accuracy into separate year classes.

Growth to adult stages occurs in lower salinity regions of the tributaries and in the Upper Bay. A large portion of the hatch attains adult size and sexual maturity in about 14 months, in late August or in September of the year following the hatch, becoming a major portion of the hard crab fisheries in the fall, winter, and spring. They contribute to the spawning stock from May through August of the third summer, and remain a very small part, probably less than 5%, of the succeeding fall, winter, and spring hard crab catch (Fig. 3).

It is unknown whether any survivors would become early summer spawners in the fourth year, but their number must be minuscule. Large, red nemerteans encapsulated between the gill plates of about 5% of the adult females in the winter and spring indicate a previous spawning history. In contrast, small, almost colorless nemerteans are evidence that the female had not extruded eggs, and represent a younger age group (year class). Juvenile nemerteans migrate from the gill plates to an extruded sponge, where they feed on the eggs, mature, mate, lay their own eggs that produce infective larvae, and as adult worms migrate to the gill chamber where they encapsulate. The timings of migration of nemerteans from the gills to the sponge and return cannot be coincidence, and probably have either a water-borne or blood borne hormone as a clue.

A modified cycle of growth is followed by that portion of the year class derived from a late summer hatch, whose magnitude probably varies every year with changing environmental conditions. Mean width of juveniles derived from the late hatch ranges from 10-30 mm by late October in the year of the hatch; legal size ($\geq$ 75 mm for commercial use) is not attained until July or later the second summer, and many do not mature until the spring of the third year at an age of 21 or more months.

When they enter the hard crab fisheries and spawn in late summer of the third year, they would still be members of the year class that matured the previous fall, but would possibly be indistinguishable from those one year younger. Estimates of the potential strength of the spawning stock should be made late enough in the spring or early summer to include the late-maturing females.

When trawl nets were deployed in the York River monthly from mid-September through mid-November from 1955 through 1982 (the last year the data were reviewed), 40-80 % of the catch in September consisted of 15-35 mm wide young-of-the-year. Changes in the bag mesh over time appeared to have no effect on the size range or percentage frequency of sizes of crabs caught: 3/4 inch mesh was used from 1955-60, 1-½ inches from 1961-63, and 1-¼ inches from 1964-72. A ½ inch liner was added in 1973. Young-of-the-year were not caught until mid-October in the following 11 years: 1956, 1958-1964, 1971, 1974 and 1979.

Growth studies of zoeae and megalopae approximate the rates of development necessary to explain the late summer to mid-fall appearance in the year of the hatch of 10-15 mm wide juveniles in the York River, but fail to approach the larger range of 25-40 mm crabs observed and commonly collected at that time by trawl nets. Zoeae progress through seven stages to megalopae in about one month (Costlow and Bookhout, 1959). Metamorphosis from megalopa to the first crab stage takes two and a half to four days at salinities of 5-30 ppt and ambient SWTs (65-75° F). Total time to grow from the zoea to a 10-mm width stage (6th instar) at various salinities is approximately 68 days (unweighted). Growth to 15 mm (7th instar) occurs in 95 days, to 25 mm (11th instar) in 176 days, 35 mm (13th instar) in 217 days, and 40 mm (14th instar) in 261 days (Van Engel, unpubl. data). Assuming similar growth rates, after hatching as zoeae on June 1, crabs would attain 10-mm on August 7, 15 mm on September 3, 25 mm on November 22, 30 mm on January 3, and 40 mm on February 16. The last three growth rates are unreasonable.

It must be concluded that both diet and the chemical and physical characteristics of the water used in the above studies were inadequate for crabs held in confinement through successive molts, and the crabs were unable to sustain faster growth rates. As well, since massive egg extrusion and hatching is not likely to occur before June 15, and may happen as late as July 15, even faster growth rates must be achieved by means I was unable to duplicate.

The indices of catchability (Tables 8a-b) are remarkably consistent in indicating trends, even though they describe the catch by different gears, in different spans of years, and were collected by different investigators. Indices represent the contributions of year classes to the various fisheries, beginning one year after the hatch for all fisheries: scrapes and dipnets, yearly trotlines, fall trotlines, winter dredges, and the combined fall and spring trotlines preceding and following the intervening winter dredges.

Not all indices represent estimates of the strength of single year classes. Trotline indices derived by combining data from Virginia and Maryland (Table 8b, col. 5) probably present false estimates of stock size, since each state's fishing practices, gear, seasons, and relative distribution of the stock were obviously different (Churchill [1917]; Sette and Fiedler, 1925). Further, in each yearly trotline catch (Table 8a, cols. 4, 7c-d, 12, 15 a-b), proportions of spring and fall catch are combined for annual estimates (Table 8b, cols. 4, 7c-d, 12, 15a-b), failing to recognize that each season was supported by different, though successive, year classes.

A scan and a test graph of the trotline indices for 1919-20 through 1924-25 (Table 8b, cols. 7a-9) can demonstrate that the Virginia and Maryland catches were significantly different and showed different trends. The only seasonal data on sizes of crabs caught in the scrape and dipnet for 1942-43 through 1945-46 (Tables 8a-b, cols. 18-19) show that differences between May data for the older year class peelers, and June through September for the younger year class, do exist. A more extensive series of indices from 1942-43 through 1953-54 (Van Engel, unpubl.), not shown here, lists differences between the two age groups and differences between years.

Can a case be developed for any cause and effect between aquatic and atmospheric environmental data, permissiveness or restrictions on fishing effort, and catch indices and landings of blue crabs? So far, there are too few data to test for any relationship between catch indices and landings between year classes 1905 to 1915 (Tables 1, 8b). However, the correlation between indices and landings for the 21 year classes from 1907 to 1943 (Tables 1-2, 8b) is 0.490 (r^2), $t = 5.98$, d.f.= 19, $p < 0.001$ (Tables 1-2, 7, 8b).

Numbers of fishing licenses are inadequate indicators of effort unless they are accompanied by numbers of units of gear, length of time gear are deployed each day, number of days of fishing, and locations of set. Scatter diagrams of the relationships between either Virginia total crabbers' licenses or combined Virginia and Maryland trotlines, and either total landings or catch indices, show no discernable trends (Tables 1-5, 8b, 14-16).

Are there any relationships between catch indices, landings, and environmental data? It might be conjectured that the initial size of the year class is determined sequentially by the size of the spawning stock; preparation of the reproductive system by favorable SWTs or some other exogenous factors for the production of ova, egg extrusion and hatching; high salinity where eggs will hatch; availability of food for zoeae, megalopae, and subsequent stages; magnitude of predation and disease on these early stages; degree of transport of zoeae to the continental shelf; and transport of megalopae from the continental shelf to the Bay.

Only a few parasites or diseases affecting extruded eggs of the adult female blue crab are now known, such as the fungus *Lagenidium callinectes* (Couch, 1942; Sandoz, Rogers and Newcombe, 1944) and the nemertean *Carcinonemertes carcinophila* (Van Engel, 1987).

Change in any of those variables could diminish or enhance the success of the year class. This initial phase encompasses a time period ranging from two or three months (mid-June to mid-September) to six months (May-October). Comparable situations affecting the success of land crops are well known and frequently demonstrated.

For development and survival of juveniles to the adult (sexually mature) stage, factors such as SWT, salinity, and food must be favorable, and predation and disease must be minimal. Estimates of survival from egg to adult, and a listing of fouling organisms, parasites, diseases and predators were summarized by Van Engel (1987).

Appropriate environmental data analyzed for their effects on catch indices and landings consisted of the following: departures of mean May state air temperatures from the long term means from 1891 to 1940 (T); May cooling degree days (CDD) at Norfolk; departures of SWTs in May and June at Baltimore (B) and Windmill Point (W) from long term means, all in the year of the hatch; and river discharges from the Susquehanna (S), Potomac (P), and James (J) rivers for summer/fall (SU) in the year of the hatch and the following spring (SP) (Table 18).

Stingray Point Lighthouse data are provided in the absence of Windmill Point reports. Landings data were extracted from Tables 1 and 7. Missing are factors that might be related to transport of zoeae and megalopae to and from the continental shelf and their survival.

The difficulties in examining the relationships between catch indices, landings, and environmental data for 1904-43 are compounded by the differing qualities of the data: some variables, e.g., discharges, are considered to be too subjectively compiled; landings data are available for only six calendar years from 1905 through 1928. Moreover, their accuracy is questionable in light of what is known of censusing methods, that geographical and gear coverage were incomplete and dealer and/or fishermen reports were mostly verbal.

Mean yearclass catch indices for 1905-1914, 1916-17, and 1925-1929 are either missing or are based on only one or two sets of data, making them less accurate estimates of the catchability of the year class, while in all other years, three to nine sets of indices are available. Additionally, the method of computing some indices by yearly ratios fails to consider seasonal variations, which would have been more accurately expressed by the logarithmic methods carried out by Pearson (1948); however, since effort data were not available or were of questionable accuracy, the latter method could not be used.

Visual analysis of Table 18 suggests that there is no single variable or combination of them to explain the range of catch indices. That conclusion is not satisfying, considering strong evidence presented earlier that the water supply cycle has a major affect on the geographical distribution of the various life history stages and on the temperature, salinity, and oxygen concentrations. As well, spring SWTs must effect the preparation of the female reproductive system for eventual egg extrusion, and regulate embryonic development, hatching, and the growth of zoeae. Obviously ignored are the mechanisms for transport of early life history stages to and from the continental shelf.

Federal and State Reports of Landings, and Results of Independent Investigations

Landings and catch increased steadily from 1880 through 1907 (Tables 1-2; Baker et al., 1909). While total Bay landings continued to rise through 1915 (Table 1), mean weekly trotline catch declined slowly and erratically from 1907 to 1911 (Tables 8a-b, col. 4), and the winter dredge catch plummeted beginning with year class 1907 (col. 10).

Assuming that the 1880 blue crab stock in the Chesapeake Bay was in a primitive state, previously minimally exploited, the gradual increase in landings and mean catch over the next 27 years through 1907 was probably due to increased fishing intensity rather than an increase in stock size. Fluctuating levels of stock size would not be discernable from available data through 1907.

Additionally, levels of fishing effort are unknown. Although crabbers' licenses for scrapes, nets, and like devices were issued in 1898 and 1900 in Virginia, different fees for specific gears were not set until 1910 (Table 4). General licenses to use any gear were available in Maryland from 1882, but fees were rarely required until 1916 (Table 17).

Discussion of factors that might have influenced rates of hatching, growth, and mortality between 1880 and 1907 has limited practical value, considering that only eight federal canvasses were made in those 28 years, and most reported landings were small (Tables 1-2). Rare comments by state commissioners provide information about the presumed effects of severe local weather on catch; however, most of those changes more likely reflected fluctuations in the intensity of fishing effort (Tables 2-4).

Roberts (1905) attributed a small catch of crabs in Maryland in 1902 to the severe winter of 1901-02 (Table 9). Roberts did not report at what time of the year the scarcity occurred, or whether soft and peeler crabs, hard crabs, or both were affected. Near-record river discharges from the Susquehanna and Potomac rivers in March 1902 (Tice, 1968) and the effects of a hurricane in the Chesapeake Bay, with date and location unknown (EPA, 1983), may have transported significant amounts of sediment into the Bay that produced sufficient turbidity to reduce radiation to SAV, or smothered SAV in layers of silt or sand. Both flood and storm may have resulted in mortalities of some portions of the stock, at least its distribution, and may have had a significant impact on fishing effort.

The midsummer/fall discharge in 1901 was the 10th largest on record at Harrisburg, fifth at Point of Rocks, and fourth at Cartersville (Tables 12-13). Low air temperatures (51 CDD) and SWTs in May 1901 would have produced an environment unfavorable for early ovarian development, hatch, and survival of early crab stages of the 1901 year class.

While the catch of hard crabs and the largest peelers from April through June 1902 would have been derived from the 1900 year class, most soft and peeler crabs caught beginning in July, and hard crabs caught from September through November, would have been derived from the 1901 year class.

Since no catch indices and landings data were obtained for 1902, no information for that year is included in Table 18. Environmental data are used to speculate on their possible effects on the 1900 and 1901 year classes (Tables 9-10, 12-13). The 1900 summer/fall (July-October) and the 1901 spring (March-May) discharges from the three major rivers would have been favorable for the hatching, growth, and development into juveniles of zoeae and megalopae (Tables 12-13). Ovarian development and egg extrusion would probably have been delayed by cold SWTs in May 1900.

Cold air in May 1901 (51 CDD, the second lowest between 1897 and 1939), and excess rainfall would have delayed growth of juvenile crabs in spring 1901; however, SWT at Stingray Point in May was only slightly below normal (Table 9). Additionally, a large number of adults of the 1900 year class could have died, the stock possibly decimated, the following winter as a result of the 1901-02 storm. Mean monthly SWTs at Windmill Point from January through April 1902 were much below normal, and in February 1902 hit the lowest point between 1882-1922. In 1901-02, minimum air temperatures in Maryland from November through February were 4, -15, -7, and -17°F respectively (U. S. Weather Bureau, 1901, 1902).

Whatever was produced might have been substantially reduced by the severe winter of 1901-02. However, high river flows, warm air and SWTs, and low rainfall in the spring of 1902 would have encouraged growth and development of the juvenile survivors of the 1901 year class (Tables 9-10, 12-13).

The increase in landings by all gear in 1904 (Tables 1-2) would have been supported by two year classes, 1902 and 1903. The 1902 year class contributed to the winter dredge fishery of January through March 1904, the spring soft and peeler catch of the late maturing females, and the spring and early summer trotline catches. It should be noted that the December 1903 dredge catch of year class 1902 would have been tallied with calendar year 1903 in federal landings reports.

The 1903 year class would have contributed to the summer and early fall 1904 scrape/dipnet fisheries, the fall trotline catch, and the December 1904 dredge catch, the latter reported as part of the 1904 landings.

Since licenses issued in Virginia between 1900 and 1910 were not gear specific (Table 4) and the number of licenses remained nearly constant, changes in gear usage cannot be determined, nor can fishing effort explain the increase in landings (Tables 3-4).

In 1902-03, summer river discharge (July-October 1902) from the Susquehanna was one of the five historical highs (Table 12), which would have been unfavorable for production of an average 1902 year class. The summer discharges from the Potomac and James were below average, which would have encouraged development of a large year class. Spring 1903 (March-May) discharge from all rivers was high, providing high quality Bay and river environments (Table 12). Spring mid-bay SWTs were cool (Table 9).

Environmental events in 1903-04 were harsh, with high summer and low spring discharges and low spring SWTs, which would have delayed ovarian and zoeal development of the 1903 year class (Tables 9, 12-13). Susquehanna River discharge in the summer of 1903 was another one of the five historical highs. Mid-Bay SWTs from December 1903 through April 1904 were abnormally low, probably echoing the March 1904 storm discharge.

An alternate approach to assessing the status of the blue crab stock was initiated by Churchill [1917], who estimated a mean catch per day by Virginia trotlines and by Virginia winter dredges. Those data were recalculated as mean catch per week by Sette and Fiedler (1925); I then recalculated the data as indices of catchability (Table 8b, cols. 4, 10). Mean trotline catch declined slowly from 1907-08 through 1915-16. Estimates of mean catch per man were either not recorded by Churchill, or ignored by Sette and Fiedler.

It is apparent that Churchill [1917] and Sette and Fiedler (1925) understood the basic life cycle of a year class. Sette and Fiedler described the contribution of a year class to the catch by different gears in different seasons as "the complete history of this particular crop," and presented the sequence of the Maryland summer scrape/dipnet and fall/spring trotline data with the Virginia dredge boat data in their Table 7 and Fig. 9.

However, when they reported trotline data from both states for 1918-25, and soft and peeler catch for 1922-24 (their Tables 1, 3-7), the data were presented by calendar years without separating the May-June older age group from the September-November younger age group (Tables 8a-b, col. 4). As well, they did not cite the dates for the beginning and end of each season. In order to reconstruct the two seasons, the dates were approximated, enabling me to calculate catch and indices of catchability (Tables 8a-b, cols. 1, 5, 7a-9 and 11).

Churchill [1917] noted that the 1907-17 Virginia trotline catch data were probably not representative of the total Virginia trotline catch, since his records were obtained from crabbers who hauled their lines by hand, and whose catch would be smaller than that of crabbers traversing their lines with engine or sail power. Also, despite increases in trotline length, which would have allowed a larger catch without substantially increasing fishing time, a downward trend in the catch occurred during those 11 years.

In graphs of trotline and dredge catch indices and bistate landings for 1906-07 through 1915-16, a few peaks and minima are evident (Fig. 4). As stated earlier, too few data for that period are available to examine the statistical relationship between catch and landings. Later records of Sette and Fiedler (1925) show that catch was markedly different in Virginia and Maryland.

Also, as stated before, since spring and fall catches were derived from two separate, successive year classes of crabs, discussion of factors that influence yearclass strength is unrelated to the magnitude of any annual index. For example, the winter dredge catch of 1906-07 and the 1907 spring and early summer trotline catches would have been composed mainly of crabs of the 1905 year class, while the 1907 fall trotline, the winter 1907-08 dredge, and 1908 spring and early summer trotline catches would have been primarily supported by the 1906 year class.

The decline in the catch from 1906-07 to 1915-16 (Tables 8a-b, cols. 4, 10) may not have been representative of fishing success throughout the Bay, since it consisted of only those catches from Virginia dredges and trotlines: (1) Virginia had smaller landings than Maryland most years through 1915, except 1908 (Tables 1-2); (2) the canvass may have been skewed toward either the most or least successful, but not the average waterman; (3) catch indices may not represent yearclass abundance, since they sometimes include the mixture of two year classes; (4) the spawning stock could have been reduced by intensified summer trotline fishing for sponge crabs, and by winter dredges to support the Virginia canning industry, the latter evidenced by the increase in dredge vessels from 1904 to 1915 (Tables 3-4); (5) overharvesting immature crabs throughout the Bay, partly to support the soft crab fishery, would have reduced the potential supply of large crabs. Overharvesting, however, was characterized by the deliberate capture of any size crab for sale to the public and restaurants for crab soups, or to crab meat picking houses (Earle, 1916).

No minimum-width cull law existed in the Bay until 1912, when Virginia set a minimum of 3.5 inches on hard crabs other than peelers. A minimum width of 5 inches for hard crabs was not enacted by either state until 1916, and a 3-inch minimum on soft crabs was set in Maryland in 1917 and in Virginia in 1922.

Although commissioners of both states referred to a "scarcity" of crabs from 1912 through 1916, attributing it to the capture of sponge crabs and not to winter dredging (Earle, 1916, 1918; Parsons et al., 1915, 1916; Kemp et al., 1917b), the trotline catch reported by Churchill was still relatively large through 1913-14 when compared with catches in later years. Virginia trotline catches increased substantially in 1912-13 and 1913-14 over those in 1911-12, supported by three successive year classes: 1910, 1911 and 1912 (Tables 8a-b, col. 4). Dredge catch data were not obtained from 1911-12 through 1913-14, but in 1914-15 had plummeted below 1910-11 values (col. 10).

Since Churchill's detailed trotline catch records do not to my knowledge exist, it is not known what portion was caught in spring 1912, derived from the 1910 year class, and what portion was caught in the fall, derived from the 1911 year class. More importantly, stock size and the magnitude of the catch from 1912 through 1915, as described by the commissioners and even those by Churchill [1917] and Sette and Fiedler (1925), may be questionable if the results of a special federal survey in 1915 are to be believed.

Responding to reports that the catch had greatly decreased in 1914 and in the spring and summer of 1915, in late 1915 the Division of Statistics of the U. S. Bureau of Fisheries canvassed the Bay crab industry for that year. The yield and value were reported as larger than the preceding canvass of 1908 for Maryland, but not for Virginia (Tables 1-2). The surveyors concluded that maximum landings and value had been reached sometime between 1908 and 1915 (U. S. Bureau of Fisheries, 1916), probably about 1912 (Redfield, 1917; H. M. Smith, 1917).

Smith stated that the estimate that maximum catch had probably been reached about 1912 was based on "information at hand." Churchill's [1917] trotline data may have been available to the surveyors in 1915, which would have shown that the 1911 and 1912 mean catch greatly exceeded the mean in 1915. Churchill's [1917] trotline data were available to and reported by Sette and Fiedler (1925).

Contrary to the reports by state commissioners of poor trotline catches in the spring and early summer of 1915, the surveyors reported bi-state Bay landings of over 50 M pounds, exceeding all landings both previously reported and in nine of the following 16 years through 1940 (Tables 1, 7). The conclusion of the Division of Statistics that maximum landings and value between 1908 and 1915 had been reached about 1912 is contrary to commissioners' reports of a decline in the mean trotline catch, but is in agreement with Churchill's finding for 1912.

Surveyors' reports for landings in 1915, on the other hand, disagree with both the commissioners' and Churchill's statements. Effort data cannot explain the differences: numbers of Virginia licenses were relatively unchanged until 1912 and were substantially fewer from 1912-1915. But some were not required in those years (Table 4). Except for scrapes, no licenses were required in Maryland until 1916.

Environmental data favorable to strong yearclass development are difficult to assess. Judged by catch indices, three intermediate-sized year classes originated in successive yearclass years from 1905-07 (Table 8b, mean indices), and possibly three more: 1909, 1911, and 1912, if yearly trotline catch indices are considered (Table 8b, col. 4). However, there is no consistent combination of environmental variables associated with any magnitude of catch indices for yearclass years 1905-15 (Table 18).

Departures of Virginia and Maryland air temperatures from the long term mean in May 1907 were -3.3° and -4.5°F, among the six lowest between 1891-1940 (Table 10); these were reflected in a large SWT deficit at Windmill Point, which continued into June. One would expect that the continued low SWT would have depressed the feeding rate and delayed the growth of juvenile crabs in May and June as well as reducing the spring 1907 trotline catch; unfortunately, detailed catch data are not available to determine what occurred.

Depressed temperatures should have delayed both the development of the female reproductive system and egg extrusion. Whether that would have delayed or reduced the egg-hatching rate of the 1907 year class to produce a smaller year class can only be speculated from the decrease in the Virginia trotline and winter dredge catch indices for 1908-09. Uncertainty about the size of either the 1906 or 1907 year class stems from the observation that the trotline index for 1908-09 covers the whole of 1908, which includes the spring and early summer catch of the year class of 1906, and the fall catch of year class 1907 (Tables 8a-b, cols. 4, 10).

Absence of or inverse relationships between catch and environmental data from 1906-07 through 1915-16 may have occurred for any or all of several reasons related to the collection of catch data: selecting the wrong combinations of months to represent effective river discharges and placing too much emphasis on all three rivers, when possibly only one, such as the James River, may be the most important.

Pearson (1948) found high negative correlations between the James River mean monthly discharge for June (-0.711 r), August (-0.672), and May (-0.509) as measured at Cartersville, and the winter dredge catch one and one-half years later for data from 1930-44. By choosing May and June discharges (incorrectly, in my opinion) and assuming they were the months of heavy spawning, the correlation with the catch was -0.756 (r); however, no confidence value was given.

In Pearson's Fig. 6, at least two extremely low and two extremely high discharges have obviously had a major effect on the placement of the regression, and probably on the correlation, suggesting that data from some of the lowest and highest discharges should be used in the correlation analysis rather than either total discharges or those lower than and higher than the means. In any data set of two variables to be analyzed for possible correlation, where other variables that might have an effect are not included, intermediate values of one or both variables can decrease the coefficient and its significance.

James River outflow may have a significant effect on the water quality in that part of the Bay where hatching and early feeding of zoeae is concentrated. Low summer/fall discharges in 1911-12 and 1912-13 may have been the bases for development of the 1911 and 1912 year classes (Tables 12-13), which supported the catch for the two years starting in the fall of 1912 and the fall of 1913 (Tables 8a-b, col. 4).

Fluctuating environmental conditions in May from 1908-11 may have promoted and then diminished yearclass strength. The May 1911 air temperature departure of +3.4°F and +5.0°F in Virginia and Maryland (Table 10) and a +7.1°F SWT at Windmill Point (Table 9) should have been factors promoting early egg extrusion and early hatching and growth of zoeae of the 1911 year class. However, the storm of January 5 through February 16, 1912, was the most severe in duration and intensity on record to that date. It caused the formation of large quantities of ice in the Bay and tributaries (U. S. Weather Bureau, 1912, 1913), probably stopped commercial dredging in Virginia, and apparently prevented monitoring of the Windmill Point SWT for those two months.

While no ill effect on the 1912-13 trotline catch was apparent (Tables 8a-b, col. 4), high mortality on adult females may have occurred, reducing the 1912 spawning population. While severe winter storms cause high mortality among adult females in the middle portions of the bay between the mouth of the Potomac River and Wolf Trap Light, it is not known whether a severe winter storm affects juveniles and adults similarly or differentially. Adult females do not tolerate low salinities at low temperatures. No effects of those low temperatures and the ice on catch, crab stocks, or fishing effort were reported by commissioners.

Since most of the suspended silt and clay discharged from the Susquehanna River would normally have been deposited in the upper 20-30 km of the Bay, less sediment would have been deposited in the upper part of the Bay following the completion of the Holtwood dam in 1910. Sediments would only be carried farther down the Bay when there were extremely large volumes of flow.

Episodic floods of the Susquehanna River in March 1913 and 1914 (Table 14) may have had unknown effects on the existent stocks and for the development of new year classes. Two floods in March and June 1916 may have affected year class development and fishing effort.

It is probable that the scarcity of crabs in the spring and early summer of 1915, continuing the reported decline in catch (Earle, 1916; Parsons et al., 1916), prompted the passage by Virginia and Maryland of 5-inch minimum-width cull laws in 1916, an increase from the 3.5 inch rule. An additional advantage of the 5-inch rule on hard crabs was to permit 3.5-inch crabs to shed an additional one or more times, increasing their weight before harvest (Parsons et al., 1916).

The 1916 cull law to release small crabs in the summer of 1916 (1915 year class) was expected to allow them to reach maturity in late summer and fall, contributing to the catch in the fall of 1916 and spring of 1917. A small increase in the 1916 fall trotline catch in Virginia did occur (Parsons et al, 1917).

A scarcity of 5-inch hard crabs was reported in the spring of 1917 by Maryland watermen, who declared that the number of legal-size crabs was too few for their demands. They pleaded hardship and requested a seasonal reduction in the size limitation to four inches in May and June and 4.5 inches in July; however, no legislative action was taken (Earle, 1918). In contrast, no scarcity occurred in Virginia in the spring of 1917 and Virginia commissioners (Parsons et al., 1918) reported that the industry was "prosperous." A difference between the states in estimated abundance has often been reported. But despite the reference to a "prosperous" industry and a small increase in the trotline and dredge catches in Virginia, catches were still very much lower than those reported for 1907 and 1908 (Tables 8a-b, cols. 4, 10-11).

The reaction of watermen to a low catch was often repeated in later years in the Chesapeake Bay. Temporary shortages were given too much weight as a request for regulatory action, or the event was misperceived as a sign of impending collapse of the fishery, with similar denials and inactivity by governing bodies. It is probable that the worsening weather in the spring of 1917 brought about a delay in crab growth and a decrease in crab availability and catchability rates. May 1917 mean air temperatures were the lowest on record between 1891-1940, with departures of -5.0°F and -5.3°F. Baltimore and Windmill Point SWTs were below 60°F (Tables 9-10).

When each state enacted its cull law in 1916, it also established a closed season on sponge crabs, females with extruded eggs, which Maryland further extended geographically in 1917 (Commonwealth of Virginia, 1916; Sessions, 1916, 1917; Parsons et al., 1916; Kemp et al., 1917a, 1917b). While the immediate planned effect of the latter ban was to set aside the breeding portion of the stock, theoretically there was greater potential for a long-term increase in total stock size. For example, zoeae hatched in mid-summer 1916 would have become adult crabs in late August or September of 1917, contributing to the fall 1917 and spring and summer 1918 trotline fisheries and the dredge catch of 1917-1918. However, those crabs originating from a late hatch in 1916 might not have matured until the spring of 1918.

In fact, more small crabs than had been seen for years was reported in Maryland in the summer of 1917 (Commission of Fisheries of Virginia, 1917). That increase was followed by a larger fall trotline catch in Virginia and Maryland, with the mean daily trotline catch at three Virginia and one Maryland dealerships reportedly rising 35-50% over that of 1916 (Churchill, [1917]; U. S. Bureau of Fisheries, 1917).

This reflected only partially the increase in the combined states' index for 1917-18 (Tables 8a-b, col. 4), but not the winter dredge catch (cols. 10-11). Those increases may have resulted from the cull law, effecting releases in 1917 of small crabs hatched in 1916, or more females spawning in 1916 (or both), or other unknown factors.

Although Virginia crabbers' licenses, principally trotlines, more than doubled from 1916 to 1917 (Table 4), the reported change in effort should be credited to a change in interpretation of the licensing laws. When different fees for specific gears were set in 1910 (Commonwealth of Virginia, 1910), the Commission of Fisheries (1911) interpreted the law to mean that no trotline license was required unless the catch was to be used for picking or canning crabs.

Eventually, Virginia commissioners (Parsons et al., 1916) recommended that all persons taking crabs for profit be taxed. Although commission minutes do not relate any action by the commissioners, a tax must have been imposed, probably between October 1, 1916 and September 30, 1917, the fiscal year of the Virginia commissioners' report. Taxing existing trotlines should not have affected actual fishing effort, only the number of units reported. General Assembly legislation in 1918 omitted all references to how the catch was to be used (Commonwealth of Virginia, 1918), thus acceding to the Virginia Commission's request and action.

The coldest winter on record in the Chesapeake Bay region was that of December 1, 1917 through January 31, 1918, with minimum air temperatures of -27°F in December and -22°F in January in Virginia, and low or freezing SWTs at Baltimore and Windmill Point (Table 9). Ice closed the Upper Bay to steam navigation as far south as the mouth of the Potomac River from December 29 through January.

Early in 1918 there was a bay-wide scarcity of crabs five inches wide and larger. The cold was followed by a fast warming trend: + 4.5 departure of mean air temperature in May was almost a record in Virginia, and + 5.1 was a record in Maryland (Tables 10, 17), while SWTs were above average (Table 9).

Most watermen expected that there would be a continued scarcity, since the severe winter had reduced the spring catch. Surprisingly, there was a great supply of large crabs "from the middle of the season on" (1918) in Maryland (Kemp et al., 1919). Mean dredge catches for the winters of 1917-1918 and 1918-1919 were larger than any reported since 1911-1912 (Tables 8a-b, cols. 10, 11).

Although an oft heard comment among Chesapeake Bay watermen, commissioners, and Bay scientists is that severe winter storms cause high mortality of crabs, the 1917-18 storm appears to have been an exception. The only plausible explanation for the large supply of crabs "from the middle of the season on" is that those crabs were derived from juveniles of the 1917 year class that had survived the winter. Little is known or has been reported on the differential mortality or survival of juveniles in winter storms.

Catch data on several crab fisheries were obtained by Sette and Fiedler (1925), who reported the mean number of crabs caught per week for the summer soft and peeler catch by Maryland scrapes and dipnets from May 1 through October 31, 1919-24. They reported in pounds the bi-state hard crab trotline catch for Virginia (April 1-November 30, 1919-25) and Maryland (May 1-October 31, 1919-25), the fall/spring Maryland trotline catch (1919-25), and the Virginia winter dredge catch (December 1-April 1, 1916-25) (partly from Churchill, [1917]) (Tables 8a-b). To ease interpretation of success of fishing, I converted catch to indices of catchability by calculating a series of ratios that were then related to a Base Year.

The Base Year for each type of fishery, e.g., scrape/dipnet and trotline and dredge, was one with an identical or similar catch in pounds made in the same type of fishery. Either the same catch index was elected, or it was adjusted for the proportional increase or decrease in the actual pounds caught in the two years, restricting the selections to indices specific to each gear type. When the difference was small, however, no adjustment was made. The base index for the 1919-20 fall/spring trotlines for Maryland and Virginia was 0.36, previously calculated for the 1916-17 Virginia trotline catch, but not adjusted for the difference between the 783 pounds in 1916-17, and 825 and 837 pounds in 1919-20, an oversight (Tables 8a-b, cols 4, 8-9). The index for Maryland's yearly catch was 0.45 (col. 7c), adjusted from the index of 0.43 for 1917-18 (col. 4); the index for Virginia's yearly catch was 0.60 (col. 7d), adjusted from the 0.51 index for 1914-15 (col. 4). An identical procedure was followed in calculating all other indices, but no details of those calculations or adjustments will be cited.

Since Sette and Fiedler had not separately tabulated the Virginia or Maryland fall trotline catches or the Virginia fall/spring data, I extracted those data from their Tables 4-5 and calculated indices for those fisheries (Tables 8a-b, cols. 7a-b, 9). My selection of beginning and ending dates for the fall and fall/spring trotline fisheries must have been close to those used by Sette and Fiedler, since the extracted mean catches in pounds for the Maryland fall/spring season in all years were exactly or nearly the same as those reported in their Table 7.

The 1919 Maryland spring/fall trotline season was described as "prosperous" (Vickers, 1920). Since all yearly, i.e., spring through fall, catches are comprised of two year classes, their indices do not estimate yearclass catchability; fall and fall/spring indices are better measures of the year class. Also, separating Virginia's catch from Maryland's may permit a more accurate description of the success of fishing in each state. However, differences in indices from the fall of 1919 through the fall of 1925 may reflect either real differences in the distribution of the stock throughout the Bay, differences in the intensity of fishing effort, or inequalities in census methods. Nevertheless, the 1922-23 year class is consistently estimated as strong in all fisheries in that period, and 1924-25 the weakest.

No adverse effects of runoff, SWT, or fishing pressure are known that would have affected the 1918 or 1919 spawning stock or their progeny (Table 18). The numbers of Virginia crabbers and dredgers were lower than previously, and since the ban on sponge crabs in July and August in Virginia was still in effect, landings in those months would have been smaller than reported in earlier years. Maryland effort in 1919 had increased, which probably accounted for much of that state's yearly increase in catch.

Total landings by all gears in 1920 (Tables 1-2) declined to a low reminiscent of 1901, and were more acutely apparent in Maryland. Mean weekly catch was lower in several fisheries in 1920-21: the combined Virginia/Maryland yearly trotline catch, Maryland fall and fall/spring trotlines, and Virginia dredges (Table 8a, cols. 5, 7a-9, 11).

Severe cold in May 1920 with air departures of -4.2° and -4.1°F in Virginia and Maryland (Table 10), and SWT departures of -3.3 and -4.2°F (the latter freezing) at Baltimore and Windmill Point (Table 9) may have slowed movement, feeding and growth of crabs, and catch. Runoff in 1918-19 and 1919-20 (Tables 12-13, 17) should have been favorable for strong development of the 1918 and 1919 year classes, but that is not reflected in the indices for 1919-20 and 1920-21 (Table 8b).

Pearson (1942) proposed that the decline in hard crab landings in 1920 might be attributed to the loss of spawning stock in 1918. However, while the spring portion of the trotline catch from April through the end of June 1920 would have been derived from the 1918 spawning, the subsequent fall catch would have been derived from the 1919 year class (see, for example, Sette and Fiedler, 1925, their Tables 4-6).

An episodic flood of the Susquehanna River in March 1920, and floods of the Susquehanna, Potomac, and James rivers in April and May 1924, may have affected stocks or development of new year classes. Landings were lower in the census years 1920, 1924, and 1925 than in 1915 and 1916 (Tables 1-2, 7; Fig. 4; Vickers et al., 1920, 1921, 1922; Maryland Department of Tidewater Fisheries, 1942). Mean catch in Maryland and Virginia was similarly low in the same census years except in 1922-23 by all gear (Tables 8a-b, cols. 1, 5-6, 7a-9, 11-12, 16).

The short rise and subsequent fall of catch between 1920 and 1925 may have been effected by different levels of fishing effort and/or abiotic factors of the environment. Maryland catches in 1922 and 1923 were reported "profitable" and "very good" (Vickers et al., 1923; Vickers, 1924), but Maryland's commissioners made no reference to seasonal differences in the catch in their calendar year reports. It is evident from Sette and Fiedler (1925, their Tables 3-6) that the best catches were made in the scrape/dipnet, fall and fall/spring trotline, and winter dredge fisheries from the summer of 1922 through the following winter and spring (Tables 8a-b), all of which were supported by the 1921 year class. Weekly scrape and dipnet catch from 1919 through 1921 was not provided by Sette and Fiedler (1925).

Sette and Fiedler derived their recognition of a year class from the close relationship between the various gear catches from the summer of 1922 through the spring of 1923. They further concluded that since the catch levels in Virginia and Maryland were closely related, the factors affecting abundance (and/or availability?) must be the same or similar in all areas and fisheries. However, it must now be recognized that factors affecting abundance at various stages of the life cycle of the blue crab and factors determining catch are not the same throughout Bay waters. This is because there are differences between the states in levels and types of fishing effort, management regulations, and the spatial and seasonal distributions of crabs, the latter being largely determined by differences in salinity, dissolved oxygen, temperature, and bottom habitat.

Legislation established Bay-wide in 1916 protecting sponge crabs in all waters in July and August was amended and extended by Virginia in 1922 (Commonwealth of Virginia, 1922). This amendment extending the dates from June 15 through August 31 remained unchanged until early 1926. The additional 15 days of protection was thought to provide a slightly larger breeding stock in June of 1922, but in most years sponge crabs are not in abundance until July and August. The decline in catchability in the following years, from 1923 to 1926, suggests that the 15-day extension made no difference, or that other factors interfered with the development of the year classes, or both.

Did abiotic factors of the environment affect the development of the year classes from 1920 through 1925? Seasonal discharges from all three rivers were favorable for development of the 1921, 1922, 1923, and 1925 year classes (Tables 12-13), and definitely unfavorable for the 1920 and 1924 year classes. Only the 1921 and 1922 year classes supported successful fisheries. The magnitude of the seasonal river discharges (July through October, March through May) was similar to the magnitude of the seasonal precipitation deficits over the six-year period (Tables 11-13).

The extremely low values of 24 CDD for May 1920 and 60 CDD in May 1924 as well as large deficits in SWTs for May and June 1920 at Baltimore and Windmill Point, and 1924 at Windmill Point (Tables 9-10, 18) indicate that conditions were too cold those years for maturation of the reproductive organs prior to egg extrusion and embryonic development after extrusion of the year classes. A contra-indicator to the likelihood of success of the 1921 year class was the low value of 59 CDD in May 1921 (Table 18), the second smallest number in the 13 years from 1897-1909, and the second smallest in the 26 years from 1914-1939 (Table 10). It is possible that the daily air temperatures were incorrectly reported by the U. S. Weather Bureau, which is suggested by the observation that SWT departures from the May mean for 1921 were small (-0.8 and -1.3)(Table 9).

The "severe" cold spell of January through February 1922 (period 1921-22 in Table 9), so cited by the U. S. Weather Bureau (1922), was milder than those that occurred previously in 1919-20 and later in 1925-26. Although the cold may have reduced the spring 1922 trotline catch (Sette and Fiedler, 1925, their Tables 4-6), sufficient stock must have been available and environmental factors must have been very favorable for the rest of the year to sustain an excellent 1922-23 commercial catch by all gear.

There were many cooling degree days in May 1922. Combined with low summer river discharges, this could have encouraged early egg extrusion, hatching, and survival of zoeae of the 1922 year class (Tables 10, 18). Warm SWTs in spring 1922 would also have eased food sources, aided rapid growth of juveniles of the 1921 hatch, and contributed to the large catches made in 1922 (Table 18).

Although the small spring 1923 river discharges would have been unfavorable for juvenile development, the 1922 year class must be considered successful, since catch in 1923-1924, excepting the fall/spring Virginia trotline catch, was larger than that of all years except 1922-23.

A 28% increase in Virginia hard crab landings from 1924 to 1925 (Tables 2, 7) is echoed by an increase in the Virginia fall trotline index (Table 8b, col. 7b). Contrary to landings reports, Virginia's winter dredge catch and Maryland's fall trotline catch declined substantially (Tables 2, 7; 8a-b, cols. 6, 16). The small catch reported by Maryland commissioners in July 1924 had not improved by 1925 (Earle, 1925, 1926). Virginia's fall trotline increases may have come from the survivors of the 1924 year class: more 25-50 mm wide (1 to 2-inch) crabs were reported in June 1925 than had ever been seen before in the Potomac River near Blakiston, Maryland (now named St. Clements Island) at the mouth of the St. Clements Bay, about 27 miles from the mouth of the Potomac River (cited in a letter in files of the Virginia Marine Resources Commission to the U. S. Commissioner of Fisheries by a Maryland fisherman).

Substantially more Virginia licenses were issued from 1922-25 for crabbing, for buying hard crabs, shedding peelers, and picking crab meat (Tables 15-16). Numbers of Maryland general "crabbers", licenses increased in 1921 and 1922, but dropped markedly after 1925 (Table 17). The incentives for the increase in fishing effort are unknown: no new size, seasonal, geographic, or economic regulations, except for those on sponge crabs, are known that would have inhibited or encouraged fishing effort, except for a recognition by watermen of the large size of the 1922-23 crab crop.

The smaller number of Virginia licenses issued in the fiscal year 1923-24 (Table 15) must be credited to a 9-month reporting year: the calendar year record (Table 16) shows no decline in 1924.

It is evident from the small Maryland trotline catches from 1924 through 1927 (Table 8a, col. 6) that the 15-day expansion of the sponge crab ban in 1922 did not, by itself, result in the desired increase in fishable stock, measured by their catchability. Also, the decline in mean weekly trotline catch paralleled the decrease in Maryland fishing effort and could not be blamed on a division of the available stock among more licensees (Table 17). Nor could it be blamed on the prohibition of capture and possession of sponge crabs, since sponge crabs are rarely found in Maryland waters.

An increase in the number of Virginia calendar year licenses from 1925 through 1927 (Table 16) would account for the increase in Virginia fall trotline landings in 1925 (Table 2) and in the mean catch (Table 8a, col. 7b).

Conferences on crabs (and oysters and fish) were held frequently from 1921 through 1926 between personnel of the U. S. Bureau of Fisheries, state government officials, state commissioners, biologists, and industry representatives. The continuation of small catches probably prompted conference agreement that a total year-round ban on sponge crabs be imposed in Virginia in 1926 (Commonwealth of Virginia, 1926). Immediately after passage of the new law, Virginia industry argued that passage of the total ban was unnecessary and ill-advised, that the winter dredge catch of 1925-26 had been plentiful, and the crab market glutted. Bay shore fishermen were claiming that their nets were choked with crabs that spring (Anonymous, 1926). Industry also predicted that the reduction in catch of female crabs in early spring and summer would lead to higher prices for crabs and crab meat, increased fishing pressure on male crabs, and false claims from other states that the shortage in the catch was caused by winter dredging in Virginia. Industry's comments about 1926 catches are not confirmed by the dredge catch of the winter of 1925-26 (Tables 8a-b, col. 16). No trotline data for the spring of 1926 from Virginia or Maryland are available for review. No legislative changes were made then, however.

Although no federal landings surveys were made from 1926 through 1928 to assess the condition of the fisheries following the total ban on sponge crabs, a 20-year record (1925-44) of fall-caught hard crabs from Maryland trotline watermen was reported by Pearson (1945, his Fig. 2). I converted Pearson's graphed yearly percentage deviations from the 20-year mean daily catch of 290 pounds to an annual mean daily catch in pounds, and calculated the ratio of each year's catch to the fall catch in 1925 (Tables 8a-b, col. 6).

Mean daily catch was first converted to weekly catch, multiplying by 3.49 an estimate of days of fishing per week obtained from data provided by Sette and Fiedler (1925). For example, Sette and Fiedler's estimate of 632 pounds per week in 1925 was 3.49 times my estimate of 181 pounds per day. Assignment of base indices was justified since no other data for the period 1925-26 through 1944-45 were available; however, data from Cronin (1982) and the Maryland Department of Research and Education (1955) later duplicated the time span, although there were some differences in catch (Tables 8a-b, cols. 6, 12; Fig. 5).

From other trotline data derived from watermen's records from Tilghman Island, Maryland (Cronin, 1944; Maryland Department of Research and Education, 1955), indices of the average daily catch per week for the calendar year (1925-44) and for the fall and fall/spring (1936-44) followed the trends in indices calculated from Pearson's 1925-44 data (Table 8b, cols. 6, 15a-c, 12). The bases for yearly trotline catch and for the fall/spring catch for Tilghman and St. Michaels (15a-d), and for the Maryland yearly catch (col. 12) were chosen by the method earlier described.

The sighting of many "small" crabs as far upbay in Maryland as the Chester River in September 1926, and in unspecified Maryland waters in August and September 1927 (Earle, 1927, 1928), suggests that factors favoring a successful hatch, survival, and growth of the young had occurred in those two years. There were more soft crabs caught in late 1927 than in many previous years, and hard crabs were in greater supply, (letter in files of the Virginia Marine Resources Commission from L. R. Carson, a Hampton, Virginia seafood dealer to the U. S. Commissioner of Fisheries).

The occurrence of "small" crabs had been mentioned only twice before 1926 in the commissioner's reports or correspondence: at Crisfield, Maryland in April and May 1916 (Commission of Fisheries of Virginia, 1917), and at the mouth of St. Clements Bay, 27 miles upriver from the mouth of the Potomac River in June 1925 (letter in files of the Virginia Marine Resources Commission from Capt. R. Lee Arnold, Blakiston P.O., Maryland, to the U. S. Commissioner of Fisheries).

Inferring the year of hatch from the size and physical condition of a Chesapeake Bay crab, when the time of year and location of capture is known, is usually easy (Van Engel, 1987). But what is the actual size of a "small" crab? In the southern end of the Bay and in its tributaries, a crab hatched in late spring or early summer may attain an average width of 20 mm by early September (Pers. obs.).

Truitt (1934) stated that 1/4 to 3/8-inch (6-9 mm) crabs were taken in the lower parts of Virginia rivers and the Bay during late October and November, and the same size crabs were caught at Solomons, Maryland in November 1931, 1932, and 1933. Churchill (1919b) reported that from April 15 to May 1, 1917, 1 to 2-inch crabs were abundant near Crisfield, Maryland, and proposed that they had migrated there the previous summer and autumn. In recent years, 10-60 mm crabs have been collected in early November in the southern end of the Bay, and north to the mouth of the Potomac River (Pers. obs.).

Migration upbay has often been reported to cease, usually near the Maryland-Virginia border, by late November or December (Truitt, 1939; Cargo and Cronin, 1951), although a few migrants may reach Pocomoke and Tangier sounds, and occasionally the Choptank River and Tilghman Island, by fall in the year of the hatch. According to Truitt (1939), numerous juveniles 1/2 to 1-inch (12.5-25 mm) wide do not usually occur in southern Maryland before the following April or May, in the mouth of the Patuxent River before June on the west shore, or Hooper's Island on the east shore of the Bay. Also according to Truitt (1934), although 3/8 to 1/2-inch crabs (9-12.5 mm) were found at the head of the Bay in mid-June in the year following the hatch, their occurrence was unprecedented; however, greater numbers were found in Pocomoke and Tangier sounds.

The Chester River is as far north of Tangier Island as Tangier is from the mouth of the Chesapeake Bay, but before 1926, "small" crabs had never been reported to have reached that river in the year of the hatch. Was their occurrence in September 1926 the result of the upbay transport or migration of juveniles representing the 1926 year class? Or were the crabs derived from the older 1925 year class that had migrated to the Chester on the usually accepted schedule?

Earle's later report (1928) of a number of "small" crabs in Maryland in August and September of 1927 did not specify where they were seen. If they had been located in Tangier and Pocomoke sounds, they could have been part of the 1927 year class; however, if they had been farther north, they may have been representatives of an older year class.

Regardless of which year classes were being represented, their rare appearance in late summer of 1926 and 1927 would suggest either an increase in stock abundance or changes in environmental conditions favorable for migration or transport, or both, and portend good fisheries. For example: (1) the 1925 year class would support the summer scrape/dipnet and fall trotline fisheries of 1926, winter dredge catch of 1926-27, and the spring trotline and spring scrape/dipnet fisheries of 1927; (2) the 1926 class would contribute to the summer scrape/dipnet and fall trotline fisheries of 1927, the winter dredge catch of 1927-28, and the spring trotline and spring scrape/dipnet fisheries of 1928; (3) the 1927 year class would support the summer scrape/dipnet and fall trotline fisheries of 1928, the winter dredge fishery of 1928-29, and the spring trotline and spring scrape/dipnet catch of 1929.

Catch data do not support the supposition that either the 1925 or 1926 year class was large. Trotline catches in calendar years 1926 and 1927 and the fall of 1926 and 1927 in Maryland were small (Table 8a, cols. 6, 12), although marketable crabs were reported farther upbay in 1927 than they had been for several years (Earle, 1928). There was, however, a substantial increase in the Virginia winter dredge catch in 1926-27, supported by the 1925 year class (Table 8a. col. 16). Success of the 1927 year class was demonstrated by substantial increases in the Maryland 1928 calendar year and fall trotline catches (cols. 6, 12).

Houston et al. (1928, 1929) reported large numbers of crabs in Virginia in the four fiscal years ending June 30, 1926 through June 30, 1929. Confirmation data are not available: Virginia catch data for that period and landings for the first three years were either not collected or had not been published. A 67% increase in Virginia 1929 calendar year landings of hard crabs over those of 1925, and a 250% increase in Maryland was reported after a federal canvass (Table 7).

Interestingly, when reporting on the status of the Virginia crab fisheries for the two years ending June 1926 and June 1927, those same Virginia commissioners (Houston et al., 1928) commented that crabs were "not seen up the rivers, creeks and coves today," because the crabs were being taken "at the mouth of the rivers, the Bay or even the capes" by more aggressive fishing practices. Whether the increased intensity of crabbing within the Bay resulted from an absence of crabs in lower saline river waters in Virginia, perhaps for some environmental reason, or because there was an economic advantage, cannot be determined at this late date.

In 1930, in studies investigating possible causes of heavy losses of oysters in Mobjack Bay and the York River in the winter of 1929-30, Prytherch (1931) described Mobjack Bay as having a soft, sticky mud bottom, low DO at the head of the bay, large concentrations of hydrogen sulfide in the mud in the upper parts of the bay, and smaller amounts nearer the mouth. He concluded that similar conditions could have caused the death of oysters. Probable conditions contributing to the depletion of DO and production of hydrogen sulfide were the rainfall in October 1929, the largest on record at that time, and a heavy snowfall in November. These would have increased stream flow, causing a heavy discharge of sediment, and washing organic matter into the bay. No deficiencies of DO or accumulations of hydrogen sulfide were reported for the York River.

There is no evidence that similar conditions existed in Mobjack Bay or any Virginia rivers on the western shore in 1926 or 1927 that would have encouraged watermen to avoid the river mouths and the bay. However, over at least the last 40 years, oxygen deficient water has occasionally flowed south along the western shore or from deeper waters of the Chesapeake Bay into river mouths.

More recent descriptions of the distribution of crabs in the Upper Chesapeake Bay are given by Miller et al. (1975), who compared numbers of different crab sizes collected from (1) Delaware Bay sites adjacent to the eastern end of the Chesapeake and Delaware Canal, henceforth referred to as "Delaware Bay"; (2) the "Canal;" (3) Chesapeake Bay sites adjacent to the western end of the Canal, including the Elk River, and hereafter referred to as the "Chesapeake Bay"; and (4) in Tangier Sound.

Sampling was conducted in March, June, August, September, and December 1971, and in March, June, and August 1972 at all sites except Tangier Sound, where sampling was done only in August and December 1971 and June and August 1972. Crabs were tabulated as "recruitment size" (smaller than 60 mm wide), "growth" stages (60-119 mm), and "mature" stages (>120 mm).

Since there is a distinct difference between ichthyologists and some crustacean biologists in their use of "recruitment" and "recruits," I will use those terms in quotation marks, or refer to crabs as "small" or by size range. My definition of a "recruit" is one entering a commercial fishery; therefore, crabs <60 mm are not "recruits," since peeler crabs are legally harvestable at the minimum size of 3 inches (76 mm). "Pre-recruit" would be an acceptable term for crabs <60 mm wide. Crabs attaining a width of five or more inches at the next molt would be "recruits" to the commercial hard crab fisheries.

My primary interest here is in the distribution and abundance of the crabs < 60 mm wide. Pre-recruits were collected in June, August, and September 1971 in Delaware Bay; June, August, and September 1971 and June 1972 in the Canal; in June, August, and September 1971 and August 1972 in Chesapeake Bay; and in August and December 1971, and June and August 1972 in Tangier Sound. The distributions encourage speculation about their origin, age, direction, and speed of travel. As stated earlier, assignment of year class depends on crab size, month, and site of collection.

Since salinities at the upper Delaware Bay sites from August through November range from 3-8 ppt (Cronin, 1954), similar to those in Tangier Sound, and the distance from the eastern end of the Canal near Delaware City to the mouth of Delaware Bay is similar to that of Tangier Sound to the Chesapeake Bay mouth, migration rates over those routes would be expected to be similar. Crabs < 60 mm at Delaware City and in Tangier Sound probably represent the same year class, although they originate from different bays. Since 10-25 mm crabs may arrive in Tangier Sound by late August or by mid-September in the year of the hatch, similar sizes might be found in the Upper Delaware Bay at about the same time.

Conceivably, in subsequent weeks they would pass the short length of the Canal westerly to the Elk River. Since growth to 40-60 mm is not attained in the Virginia portion of the Chesapeake Bay until October or November in the year of the hatch, crabs in that size range caught in August or September in any part of the bay are **assumed** to have been derived from a year class one year older.

To continue the speculation, migration from the mouth of the Chesapeake Bay to the Elk River, a distance of about two and a half times that from the bay mouth to Tangier, was probably not complete by June or even as late as September in the year of hatch, and crabs > 25 mm found at the mouth of the Elk River in those months should be aged as one year older than the year of collection. Continued migration of the youngest year class upbay would place them in the Elk River and possibly in the Canal in June the year after the hatch, the areas "reinhabited" in the spring, as Miller et al. (1975) stated, which is consistent with Truitt's (1934) remarks.

However, as Miller et al. (1975) suggested, migration from the mouth of Delaware Bay to the western end of the Canal in the year of the hatch could place small crabs in the Elk River area in August and September. When collection dates, growth rates, and travel distances are considered, possibly two year classes are represented in the size frequency distributions of "recruitment sizes," up to 59 mm, shown for the Upper Delaware, Canal, and Elk River areas in June, August, and September 1971 (Miller et al., 1975, their Fig. 3).

The occurrence of "small" crabs in Maryland's Chester River in September 1926 was considered unusual by Earle (1927) because it was their first appearance upbay anywhere north of Tangier Sound after a lapse of many years, and none had ever been reported that far north. That the migration to the Chester River in the year of the hatch may not have been unusual was demonstrated by Hines et al. (1990), who collected 10-40 mm crabs (modal size 25 mm) in the Rhode River, Maryland, from September through November, and similar sizes the following April, as shown in average size frequency distributions from 1981-1988 (their Fig. 5).

The Rhode River mouth is about 12 nautical miles SW of the Chester River mouth. Not only is the distance between those river mouths negligible, but migration (transport) times could be considered nearly identical, although flooding, when travel usually occurs, begins earlier on the eastern side than the western side of the Bay.

Hines et al. (1990, their Fig. 3) found the mean monthly abundance of crabs larger in 1984, 1985, and 1986 than in the other five years of the survey. When the histograms for July 1984 and 1985 (their Fig. 6) are compared with the composite for July in their Fig. 5, it is clear that the 50-100 mm size classes in July 1984 and 1985 were derived, respectively, from the 1983 and 1984 year classes.

Similar comparisons demonstrate that crabs larger than 100 mm in July both years were derived from the older year classes of 1982 and 1983. Since it is common for an unknown number of individuals to be the progeny of a late hatch that did not mature until the spring of the third year, a percentage of the July 1984 and 1985 crabs in the >100 mm size range may have been derived from year classes 1981 and 1982. Year class assignment is necessary when the effects of biotic and abiotic factors of the environment on the success or failure of a year class are being considered.

Seasonal river discharges in 1925-26 and 1926-27 were dissimilar. Summer flows in 1925 were among the five historical lows, favorable for strong yearclass development, but were above average in 1926, except in the James River. Spring flows were low in all rivers in 1926, but high in 1927 in two rivers, and low in the James (Tables 12-13, 18).

Since seasonal spring flows and precipitation in 1926 were below the means, resulting in higher salinities upriver and upbay, extensive juvenile crab migration to Upper Bay areas could have occurred; however, other and smaller spring flows occurred in earlier years that could have been favorable to upbay migration or transport, but were never reported (Tables 10-13).

Air temperature and CDD were lower in May 1925 than in 1926 (Table 10), but SWTs at Baltimore in May 1925 and 1926 were not significantly different. They were above 60°F, but only sightly below the long-term mean (Table 9), suggesting that those temperatures were neither depressing nor stimulating development of the reproductive system. To conclude, the occurrence of "small" crabs did not guarantee a strong year class, evidenced by the small Maryland yearly and fall trotline catches in 1926 and 1927 (Table 8a, cols. 6, 12). Since construction of the Conowingo dam on the Susquehanna River did not begin until March 1926 and was not completed until 1928, and the Chesapeake and Delaware Canal was not converted to an unobstructed waterway until 1927, no effects from those projects could have altered river or canal discharge in 1925 or 1926.

The most dramatic rise and fall of catch and landings in any of the first 60 years of the Bay blue crab fisheries is documented by the Maryland yearly and fall trotline catches from 1928 through 1933 (Table 8a, cols. 6, 12) and total bay landings from 1929 through 1933 (Tables 2, 7; Fig. 5). Prior to 1926, hard crabs were scarce in the Bay, rivers, and creeks draining the eastern shore of the Bay north of the Little Choptank River and on the western shore north of the Patuxent River, and crab fisheries farther up the Bay were nearly abandoned (Earle, 1930). The 1929 migration of hard crabs extended as far north as Chesapeake City on the Elk River, the farthest observed for "twenty years" (Earle, 1930). Maryland's yearly and fall trotline catches more than doubled from 1927 to 1928. That trend continued to a peak in 1930, but then began declining to the pre-1928 catch level by 1934 (Fig. 5). The catch of hard crabs increased by 30%

in 1929 over that of 1928, and by nine % in peelers (Earle, 1930). Bay landings in 1929 were double those of 1925, 75% produced by trotlines.

From 1930-31 through 1933-34, landings did not follow the same trend as catches (Fig. 5). The continued, and striking, migration of crabs to the Upper Bay (Earle, 1931) resulted in an increase in landings of 25% in 1930 over that of 1929 (Tables 2, 7), which was reflected in the large yearly and fall trotline catches in Maryland (Table 8a, cols. 6, 12; Fig. 5). Nearly the same high level of landings was maintained through 1933 (Tables 2, 7).

Unfortunately, other than winter dredge catch reports, no independent surveys were made in Virginia from 1927 through 1930 that might have documented whether similar or different trends in catch by other gears occurred. Winter dredge indices tripled from 1926-27 to 1931-32, the latter supported by the 1930 year class (Table 8b, cols. 14, 16-17).

The yearly and fall Maryland trotline catches from 1928 through 1933 were supported by year classes 1927 through 1932, while the dredge catches from December 1926 through March 1927, and the three years from December 1931-March 1932 through December 1933-March 1934 were primarily derived from year classes 1925, 1930, 1931, and 1932; no dredge data were collected from December 1927 through March 1931.

Since no federal census of the fisheries was made in 1928, the success of the 1927 year class can be estimated only by the independent surveys of catch by Cronin (1944), the Maryland Department of Research and Education (1955), and Pearson (1945). We can infer from the large calendar year landings that year classes 1927 through 1933 were larger than any previously experienced. Federal reporting of landings by month did not begin until 1960 and has been continued by Virginia at that frequency, allowing for approximation of Biological Year landings, but published reports from Maryland have recently ceased.

Migration of "small" crabs into Maryland waters after 1927 had not gone unnoticed or unreported, for many had been seen by November 1 in 1929 and 1930 (Earle, 1930, 1931), although their location was unfortunately not reported. Because small crabs had not been reported in Maryland in 1928 does not mean they had not occurred, but the omission denies the opportunity of concluding that there were consecutive year classes penetrating Maryland waters since 1927.

The decline of Maryland yearly and fall trotline catches beginning in 1931 and of the Virginia dredge catch beginning in the winter of 1932-33 (although the latter may have started its decline earlier) (Table 8a, cols. 6, 12, 14, 16-17), and the decline in the number of Virginia licenses (Tables 5, 15-16) are inconsistent with the relatively high level of landings persisting through 1933 (Tables 2, 7). This comparison emphasizes the uncertainty as to which data sets, landings or catch, represent the better estimate of the real availability of crabs, or whether either one does. Effort data are least likely to be incorrectly reported by the states, although their recording of only the revenue derived from license sales has led me to errors in conversions to numbers (Tables 15-16).

Following the six-year complete ban on sponge crabs in Virginia beginning in 1926, a reversal of the ban was enacted in 1932, permitting both capture and possession, from April 1 through June 30. This was done to satisfy a mounting consumer demand for crabs and crab meat, which could be partly supplied by sponge crabs, and because sponge crabs were interfering with the catch of hard crabs by Virginia trotline fishermen (Armstrong et al., 1932; Commonwealth of Virginia, 1932; Earle, 1932a, Pearson, 1942). Presumably sponge crab protection continued for the remaining months of each year, i.e., after June 30, since no other alterations of the 1922 and 1926 laws were made.

Maryland lobbied in vain against the three-month open season (Earle, 1932a). Pearson (1942) stated that the law was changed for economic, not conservation reasons, and added that protection of sponge crabs in July and August was of questionable conservation value because "ambiguous and poorly drafted laws have prevented effective enforcement" (Pearson, 1945, p. 4.). He did not elaborate on his comments.

Maryland commissioners reported a "bountiful" and "quite plentiful" supply in 1932 and 1933, which slightly exaggerates the catches cited by Cronin (1944), the Maryland Department of Research and Education (1955), and Pearson (1945) (Tables 8a-b). A marked decrease followed in 1934 (Earle, 1932a, 1932b, 1933, 1935). Hard and soft crabs remained abundant in Virginia from 1930 through June 1932, with 1930 catches the "largest of any year on record" (Armstrong et al., 1932; Tables 2, 7, 8a).

An abundance of "baby" crabs was seen in Virginia in the spring of 1931 (Chinn et al., 1931), which, because of the season of occurrence, are assumed to have been the progeny of the 1930 year class, since development to a small crab stage could not possibly have been attained under the best of circumstances before late July or early August, and not until early September in average years. Although the 1933 hard crab catch in Virginia was reported ample, soft crabs were not in large supply (Table 2; Kellam et al., 1934). Undoubtedly, the destruction of boats and gear during the August 1933 storm and the necessary shift to other gears (Tables 5, 15-16) were responsible for a substantial portion of the decline of landings in 1934 and 1935, and perhaps in 1936 (Tables 2, 7).

A Retrospection on Conditions Occurring From 1928-1934

Three groups of factors, separately or in combination, that may have affected year class strength and subsequent catch and landings from spring 1928 through March 1934, are outlined in sections a1-a3, b1-b10 and c1-c3 following, and then in detail. Additionally, the accuracy with which any or all of the data were collected, analyzed, interpreted, or recorded cannot be assured.

Section a1-a3: levels of success in reproduction, i.e., year class size and the total size of the crab population; laws and regulations affecting the catch; and the distribution of the stock throughout the Bay and its tributaries.

Section b1-b10: biotic and abiotic factors of the aquatic and atmospheric environments, and some socioeconomic factors.

Section c1-c3: intensity and diversity of fishing effort.

Factor (a1): The principal contributors to catch and landings from 1928 through March 1934 were the large year classes from 1927 through 1932. It can be correctly argued that the 1926 year class contributed a small amount to the spring and early summer 1928 trotline landings (Tables 2, 8a, col. 12); however, that year class would not have been involved in the fall 1928 trotline catch.

(a2) What is the relationship between sponge crab protection and year class strength from 1926 through March 1933? Following the four years (1922-25) during which sponge crabs were protected from June 15-August 31, for the next six years, 1926 through 1931, capture and possession of sponge crabs were prohibited throughout the year in all Virginia waters. A reversal of the total ban was enacted in 1932 so that catch and possession were permitted for three months each spring (through June 30) to satisfy mounting consumer demands for crabs and crab meat, and because sponge crabs were interfering with the catch of hard crabs by Virginia trotline fishermen (Armstrong et al., 1932; Commonwealth of Virginia, 1932; Earle, 1932a, Pearson, 1942).

Presumably sponge crab protection continued the remaining months of each year, i.e., after June 30, 1932, since no other alterations of the 1922 and 1926 laws were made. Maryland lobbied in vain against the three-month open season (Earle, 1932a). As previously noted, Pearson (1942) stated his objections to the new law.

Since, in recent years, the number of sponge crabs has usually been low until middle or late June, and assuming that the same condition existed in the early 1930's, the impact of the open season on reproductive potential of a 1932 year class was probably minimal. In substance, the total ban from 1926 through 1931, if enforced, could have permitted protection of a large brood stock, which, given other favorable biotic and abiotic conditions, could have produced several successful year classes of crabs.

(a3) Relatively large indices of fishing success, which correctly or not are assumed to be highly correlated with yearclass strength, are shown for Maryland yearly and fall trotline catches from 1928 through 1931 (1928-29 through 1931-32, Tables 8a-b, cols. 6, 12), and Virginia dredge catches from 1931-32 through 1933-34 (cols. 14, 16). That they show markedly similar trends adds to their credibility as representing a common Bay stock, probably accompanied by similar levels of fishing effort and catchability in both states. Dredge data are not available for the earlier years, and scrape/dipnet data are not available for any of those years.

(b1) Whether submerged aquatic vegetation (SAV), particularly eelgrass (*Zostera marina*), as well as marshes and unvegetated sand/mud flats in Chesapeake Bay and its tributaries are required to maintain a healthy blue crab population is still being investigated, but they are generally considered important habitats for growth and development of different life history stages. However, they may not be of equal value. Occupancy, biomass, and secondary production of juvenile crabs on an unvegetated sand bottom from October 1980 through June 1981 at a site on the north side of the York River mouth was one order of magnitude lower than on an adjacent vegetated bed (Penry, 1982).

Decimation of eelgrass in the Bay in 1931-32 was originally only verbally described (Kemp et al., 1983). Its geographic limits in 1937 were determined when aerial photographs were examined (Orth and Moore, 1984) and compared with anecdotal information from 1931-32. Where eelgrass, the dominant species, had formerly been dense, only patches or less dense areas remained in 1937, but some recovery apparently had occurred in the intervening five to six years. Bay landings began to decline in 1932, and by 1934 were only 62% of 1931 landings; not until 1947 were 1931 levels attained.

Landings per unit of effort (CPUE) by Virginia units of trotlines, hard crab scrapes, winter dredges, and number of vessels and boats dropped in 1934. Maryland trotlines and hard crab scrapes dropped in 1934 also; however, CPUE of soft and peeler scrapes increased (Van Engel and Harris, 1983).

While the almost immediate decline in landings in 1932 attests to the dependence of blue crabs on SAV, the later fall might also be attributed to the historic storm of August 23, 1933. Boats, gear, docking facilities, and processing plants were destroyed in the storm (Daily Press, 1984), substantially reducing fishing effort that year, with no recovery by 1934 and slow replacement in later years.

The storm caused the shifting of bottoms, undoubtedly resulting in the displacement of the stock to areas usually unfished. A long time elapsed before successful fishing resumed. It is possible that the storm destroyed most of the 1933 year class, then present as zoeae, megalopae and small juveniles, as well as much of the 1932 year class present as juveniles or adults, resulting in very small catches in 1933 and 1934. Under those circumstances, it is difficult to perceive landings volumes as large as those reported. Possible effects of that storm on SAV have not been reported, to my knowledge.

A major decimation of SAV was reported in 1972, presumed to have been an effect of Tropical Storm Agnes (Chesapeake Bay Research Council, 1973), but also attributed to a decline that had slowly developed since the mid-1960's (Kemp et al., 1983; Orth and Moore, 1984). The June 19-23 storm was first reported to have had no noticeable effect on crab survival, but there was an abrupt translocation of crabs downstream that lasted about two weeks.

Following an abrupt decrease in total Bay landings in 1973, landings from 1973 through 1980 never attained the pre-1972 levels (Van Engel and Harris, 1983). While the loss of *Zostera* beds on which crabs are dependent has been considered the principal factor effecting the decline, other compounding factors such as siltation covering food supplies or the mortality of breeding stock, juveniles, and larvae may have been partly responsible. The choice of alternate habitats such as marshes has not been confirmed.

Storm losses of gear and changes in preference for gear types, some of which began in 1970, further obscure causes of changes in Bay landings. Later consequences of the storm or gear changes cannot be determined from available records.

(b2) Documentation of abiotic factors in the aquatic environment and of climate variables in the mid-1920s and early 1930s is limited. Severe winter storms over the bay were rare, occurring only in November 1929. Mean statewide Virginia and Maryland air temperatures and SWTs in May and June at Baltimore remained above 60°F (16°C) in all years, although in some years they were slightly below the long term means (Tables 9-10).

Egg extrusion may have been normal but not early in most years, and hatching rates slow until mid-June, after which hatching could have occurred in 10-14 days. Although it was suggested that very cold weather during the last 10 days in April 1931 caused the delay in the usual spring soft and peeler catch in Tangier Sound by retarding the development of crabs (Conservation Department of Maryland, 1931), there was no departure of SWTs from the April mean at Baltimore, and only a small departure in June (Table 9).

(b3) Cooling degree days (CDD) during May in the year of the hatch had the highest single correlation, 0.59% (r^2), with subsequent hard crab landings, and were used in a multiple correlation analysis that explained 86% (r^2) of the variation in commercial hard crab landings one and a half years later, from 1964 through 1975 (Van Engel and Harris, 1979). It was assumed that the results of the study were applicable to other time periods. At the time of the study, sources of SWT data had not been located, and CDD were used as a surrogate.

In the yearclass years 1926-34, the relationship between CDD and SWT at Baltimore appears curvilinear (no regression was computed). Over that period, there are similar trends in CDD, SWT, and the indices of catchability in the same year for most, but not all years—not one and one half years later as demonstrated in the multiple correlation analysis. A major departure occurred in 1933 when there was an inverse relationship between catch indices and CDD, which continued through 1934. The large, positive departures of CDD and SWTs in 1933 could have been favorable for the production of a very large 1933 year class.

(b4) Severe drought in the Bay area occurred from early 1925 through mid-1926 and in 1930 (Earle, 1931; Table 11). May precipitation in the region in six of the years between 1923 and 1930 (Table 10) was less than the 50-year (1891-1940) Virginia long-term mean of 3.71 inches, with four of those in consecutive years 1925-28. In seven years, Maryland had less than the 46-year mean of 3.50 inches; the six years from 1925-30 were consecutive. The latter rainfall deficit, accompanied by small discharges, occurred from March through May from all three rivers in only four years—1923, 1925, 1926 and 1930—but was reflected as low discharge only from the James River in 1927 and 1928 (Tables 12-13).

Those small spring lows would not have been favorable to the development of juvenile stages of year classes 1924-27, 1929-31 and 1933. The extreme deficiency of rainfall in 1925, 13 inches below normal in Virginia (February-September, incl.), 6.96 inches below normal in Maryland (March-September), documented the driest growing season on record to that date (U. S. Weather Bureau, 1925). March-May discharges from the Susquehanna and James rivers in 1925 were among the five historical lows (Tables 12-13).

(b5) Theoretically, a very large body of warm, high-salinity water from mid-June through August in the southern end of the Bay where water from all the rivers and the Upper Bay converge, would be conducive to hatching and growth of zoeae and their metamorphosis to megalopae. Low flow through October would also increase the probability of retention of those stages within the Bay. In winter and spring, since juveniles are found in the low salinity portions of each of the rivers and in the Upper Bay, the degree and quality of support of juveniles would vary widely as a result of their differing watersheds.

The frequency with which low summer flow is associated with large yearclass success, whether or not it is followed by a high spring flow, suggests that low summer flow is the more important factor; however, no definition of "favorable" low or high flow for any season has been statistically demonstrated. Combinations of summer high discharge with either a spring low or high, considered to produce an unfavorable aquatic environment for development through the early crab stages, were characteristic of all river discharges from 1927-28 through 1929-30, except for a summer low/spring low from the Susquehanna River in 1929-30 (Tables 12-13, 18).

Outflows from all rivers from 1930-31 through 1932-33 probably established favorable environments for all life history stages. However, spring flows were so small in 1930, 1931, and in one river in 1932 (Tables 12-13, 18), that they might have contributed to extensive migration upriver and upbay, resulting in crowded habitats, food shortages, and cannibalism.

(b6) Blockage of the Susquehanna River by the Holtwood and Conowingo dams is reported to have affected migrations of shad and river herring, resulting in the subsequent decline in those species' stocks in succeeding years (Pers. comm., R. St. Pierre). Juvenile male blue crabs, but not females, migrate to fresh waters in the upper reaches of Virginia's rivers (Van Engel and Wojcik, 1957) for further growth and development, but the relative success of a year class is probably not affected by blockage of migration to fresh waters in Virginia or Maryland because of the low number of males usually involved. However, blocked migration of males and females to fresh water nursery grounds in other geographic regions, e.g., Lake Pontchartrain, Louisianna, might prevent the development of juveniles of a valuable stock if no other nursery grounds were available.

(b7) Could construction and/or operation of dams nearest the mouth of the Susquehanna River have affected water volume or sediment discharge during the 1926-1933 water cycles? Resolution of that question requires knowledge that is not available for that period: of construction plans and timing of work, measurements or estimates of the concentrations of coarse and suspended sediments and where they were deposited, and potential effects of the altered state of the bottom on blue crab distribution and abundance. One possible approach is to examine other concurrent events as well as some occurring in later years.

Construction of the Conowingo dam began in March 1926, a few months before sighting many small crabs near the Chester River in Maryland. Since the Susquehanna spring water discharge in 1926 (1925-26 water cycle) was low (Tables 12-13), sediment discharge would have been unusually low, and alterations of the bottom in the upper 25-30 km of the Bay would have been minimal. As well, water year discharges were below the 60-year mean of 34,430 cfs in five of seven years from 1919 through 1925 (Table 12).

The absence or scarcity of juvenile crabs in the upper bay prior to 1926 cannot be explained by any major alterations of the bottom or increases in turbidity resulting from the Susquehanna River flow. While construction was continuing in 1927 and early 1928, coarse sediment discharge may have decreased substantially and may have ceased by March 1928 when the dam was completed.

Sightings of hard crabs of the 1928 and 1929 Chesapeake Bay year classes, in the Elk River in November 1929 and 1930, occurred after the completion of the Conowingo dam. While there was no water discharge between 1800 and 0800 during the week, discharge was routinely allowed at 0800 hours every day except Saturday and Sunday (Pers. comm., R. St. Pierre). Whether any coarse sediment was discharged then is unknown. Susquehanna outflow in the spring of 1928 was only slightly above average, but spring 1929 outflow was the third largest between 1892 and 1944.

Although no estimate of suspended sediment discharge from all sources from March through May 1929 has been made, it might have been similar to that deposited in later storms. Mean annual deposits of sediment from suspended clays and silts in the upper 25-30 km of the Bay in normal years is about 0.7 cm, which is reworked and redistributed by tidal currents and wind waves the rest of the year (Schubel and Hirschberg, 1978). While deposits in the Upper Bay from all sources caused by Tropical Storm Agnes in June 1972 ranged from 10-30 cm (mean 15 cm), larger deposits in the upper bay resulted from the runoff in March 1936 from two successive storms plus melting of deep snow (Schubel and Hirschberg, 1978).

Assuming that deposits in the Upper Bay from the spring 1929 Susquehanna outflow plus material from other Upper Bay sources were similar to deposits in later years, major alteration of the bottom and of the benthic community must have occurred, yet such changes did not obstruct the northward migration of some juvenile crabs to the Elk River area, and apparently did not affect abundance of the 1929 year class.

Neither the Conowingo dam construction schedule nor the amounts of coarse or suspended sediment discharge appear to have any relationship to the successful production of the 1926 through 1929 year classes, the sightings of juvenile crabs in the upper bay in August and September 1926 and 1927, or of hard crabs by November 1929 and 1930.

(b8) Following the conversion of the Chesapeake and Delaware Canal to an unobstructed waterway in 1927, freer movement of brackish water species between the Chesapeake and Delaware bays was possible. Only minor increases in salinity over short distances in the extreme northern end of the Chesapeake Bay were expected to result from diversion of Bay water to the east (Cronin et al., 1976). Minor salinity changes could not affect normal distribution patterns or development of the Chesapeake Bay stock of blue crabs.

It is conceivable that some of the crabs seen in the Chester River area in August and September 1926 and 1927, but particularly those seen in the Elk River by November 1929 and 1930, had migrated from Delaware Bay westward through the Canal. Miller et al., (1975) concluded that recruitment to the Chesapeake Bay through the Canal seemed of little significance.

(b9) While Maryland may have encountered more competition in sales of crabs and crabmeat as a result of the 1932 Virginia law regarding sponge crabs, none of the sponge crabs could have been legally transported into Maryland—that state's 1916 prohibition of capture and possession of crabs with "visible eggs" at any time of the year was not changed until the early 1940s.

(c1) The number of Maryland's all-inclusive "crabbers" licenses remained relatively low and constant from 1926 through 1929, then substantially increased in 1930 and 1931 (Tables 5, 17). There is a direct relationship between the phenomenal increase in the Maryland yearly and fall trotline catches from 1928-30, their subsequent decrease (Table 8a, cols. 6, 12), the exponential increase in Maryland's landings (Tables 2, 7), and the number of crabbing licenses.

How the federal government obtained Maryland trotline license data for 1929 and 1930 was never described, although it could have been by personal contacts: specific licensing of trotlines in Maryland was not required until 1931, to my knowledge (Table 5). Virginia "crabbers" licenses, which included the ordinary trotline, continued to decrease from 1928 to 1933 (Tables 5, 15-16), reflecting an inverse relationship with landings from 1929 through 1931 (Tables 2, 5, 15-16). Differences between federal and state license data (Tables 5, 15-16) are largely because of different reporting periods: calendar year by federal agencies and fiscal year by state agencies.

(c2) Total landings and landings by specific gears remained high through 1933 and did not substantially decline until 1934 (Tables 2, 7), but Maryland's yearly and fall trotline catches slowly declined after the 1930 peak (Table 8a, cols. 6, 12), again showing a difference between catch and landings (see paragraph c1, above, for a discussion of fishing effort). The slow decline in indices of catchability and little change in crab landings are in contrast with the abrupt decimation of eelgrass in 1931-32. This suggests that either alternate habitats, possibly with more dependence on marshes, were quickly chosen by blue crabs during that period, or that censusing methods were inaccurate.

(c3) The stock market collapse and the economic depression of the early 1930s drove men to seek jobs that entailed little or no expense, which presumably led to an expansion of the Virginia and Maryland crabbing industries and increases in sales as well as greater public fishing effort for personal and local consumption of crabs and crab meat. The decrease in trotline and scrape licenses and the shift to dipnets in both states in 19931 and 1932 was probably an attempt to avoid paying license fees (Van Engel and Wojcik, 1965b).

Summary of Retrospection

Conditions that may have increased stock size and improved fishing success from 1927 through 1930 included (1) increased protection of the spawning stock of adult females; (2) warm SWTs in 1927, 1929, and 1930, which may have promoted timely development of the reproductive system in preparation for egg extrusion, early egg extrusion, and embryonic growth, and set the stage for production of strong year classes; (3) warm aquatic environments in May and June 1929 and 1930 that may have permitted earlier and faster feeding and growth rates, which resulted in larger stocks more immediately available for harvesting; (4) seasonal river discharges from the James River in 1926-27, from the Susquehanna in 1929-30, and from all three rivers in 1930-31 that were favorable for growth and survival of zoeae, megalopae and juveniles; and (5) suitable substrate for protection and nutrient source.

Conditions not favorable for growth and survival of early life history stages were (1) large river discharges from the Susquehanna and Potomac in the summer of 1926-27, large summer discharges from all three rivers in 1927-28 and 1928-29, and from the Potomac and James rivers in 1929-30; and (2) cool SWT in May and June 1928. There are no statistics on transport mechanisms for that period of time that might have either ensured the retention within the Bay of a substantial portion of the megalopae and juveniles, or the reverse transport of megalopae and juveniles from the continental shelf to the Bay, both of which are presumed to have impact on the Bay fishable stock size.

Further, the slow decline in catch and landings from 1931 to mid-1934 could have been the combined effects of (1) seasonally average SWTs that permitted normal egg production and embryonic development of zoeae, and seasonally normal feeding and growth rates for juveniles in 1931 and 1932, demonstrated by the insignificant departures of SWT at Baltimore; (2) an inhospitable aquatic environment expressed in small spring river discharges from 1930 through 1932, and in 1934 that neither enhanced growth nor improved survival of juveniles; (3) decimation of SAV beds in 1930 and 1931 that removed protection and nutrient sources; and (4) the biological, social, and economic effects of the August 1933 hurricane.

Although sponge crabs were protected year-round through 1931, that alone did not ensure the production of a strong catch in 1932 and 1933. Environmental conditions on the continental shelf in the fall in those years, which may have interfered with or enhanced the return transport of megalopae from the continental shelf to the Bay, have unfortunately not been studied for any year between 1880 and 1940.

Conditions Occurring from 1934 Through 1941

In 1934, Virginia reversed the 1932 three-month spring open season on sponge crabs and prohibited the catching of sponge crabs from the end of the dredge season (March 31) through June 30 (Commonwealth of Virginia, 1934). This amendment was ill-conceived, for it became logistically and economically difficult for commission boats to patrol the lower bay day and night. However, the concept of protection eventually led to the establishment of a Lower Bay sanctuary several years later.

The plummeting Virginia catch and landings in 1934 (Tables 2, 8a, cols. 14, 16) prompted the Virginia Commission in 1935 to close the last two weeks of the April 1-June 30 open season on sponge crabs. Because of the almost continuous, subsequent decline in catch (except for small increases in 1936) the season was shortened one to four weeks more from 1936 through 1938. Sponge crab protection for the remainder of each year was unchanged. As stated earlier, those changes would have had minimal impacts on the size of any of the breeding stocks since sponge crabs are usually rare before mid-June in most years.

A second, though less dramatic, rise and fall of Bay landings similar to that from 1928 through 1934 occurred between 1935 and 1941, with an abrupt drop in 1940 and 1941 (Tables 2, 7; Fig. 5). Small landings were echoed in the 1940-41 spring and fall Maryland scrape/dipnet and trotline catch, but are better shown by the indices that compared catch by week; Virginia's dredge catch remained almost constant (Tables 8a-b).

Virginia commissioners' comments in 1934 and 1935 were limited to noting the large supply of "small" crabs at the end of June 1935 (Kellam et al., 1935a, 1935b), and in the latter part of August 1935 (Duer et al., 1936). Reports that the 1935 Maryland landings were over 22 M pounds and that Virginia's landings were greater than those for many previous years (Duer et al., 1936) differ substantially from the smaller landings in federal accounts and by independent investigators (Tables 2, 7, 8a-b; Fig. 5).

If total Bay landings from 1934 through 1939 are measures of yearclass strength, then each succeeding year class from 1933 to 1938 was stronger than the previous one (Table 7). However, there are unexplainable differences between the two states' landings from 1934 through 1936 (Tables 2, 7): Virginia total hard crab landings fell slightly in 1935 and quickly recovered in 1936, while Maryland landings plummeted in 1934, recovered slightly in 1935, and fell again in 1936, principally in the trotline landings.

The sequence of support from each year class was disrupted, either environmentally, biologically or by methods of collection and/or calculation of landings: while Maryland landings in 1937 were smaller than in 1938, the difference could have resulted from fewer Maryland trotline licenses the first year (Tables 5, 17). Gear usage, which changed between 1930 and 1934 because of the economic depression and the August 1933 storm (Tables 5, 15-17), slowly reverted to more efficient gear types after 1934 as evidenced by the decrease in dipnet licenses and the increase in trotline and crabbers' licenses in Virginia (Tables 5, 15), and the increase in scrapes and trotlines in Maryland (Tables 7, 17).

Severe winter storms occurred from late January to early March 1934 and from late January to late February 1936 (U. S. Weather Bureau, 1897-1939; Duer et al., 1937), reflected in the large negative departures of SWTs at Baltimore (Table 9). In both years, ice in the rivers and on the Bay was considered the worst since 1917-18 (U. S. Weather Bureau, 1897-1939). Crab mortalities those winters were cited by Virginia commissioners (Armstrong, 1937), but Maryland commissioners noted only the winter's severity. Cooling degree days (CDD) were high in May and June in all years from 1934 through 1939, except 1935 (Table 10). That pattern was reflected in the May positive departures of SWTs at Baltimore, except in 1934 and 1935 (Table 9). Fewer CDD and larger negative departures from the SWTs at Baltimore in May 1935 would have provided unfavorable conditions for early egg extrusion and embryonic development of the 1935 year class, which would support the 1936-37 catches. Catch and indices for scrapes/dipnets and the yearly and fall trotlines were substantially lower in 1936 (Tables 8a-b; Fig. 5).

Seasonal discharge cycles least favorable for zoeal and megalopal development occurred between 1935-36 and 1937-38 from all three rivers, with high summer flows in the three rivers (historically high in the Potomac and James in 1937-38), and low winter/spring flows in the three rivers in 1937-38 (historically low in the Susquehanna and James; Tables 12-13). The episodic floods of the Susquehanna, Potomac and James rivers in March 1936 (Speer and

Gamble, 1964; Tice, 1968) (Table 14) have been reported to have had discharges volumes for the Susquehanna and Potomac rivers larger than in any preceding year and more than recorded for Tropical Storm Agnes in June 1972 (Schubel and Hirschberg, 1978).

A low catch by scrapes/dipnets and yearly and fall trotlines in Maryland in 1936, based on CDD and river discharges, would have been accurately predicted, while a low summer/fall and winter/spring catch forecast for 1938-39 would have been inaccurate when based solely on discharges (Table 8a). River runoff from the Potomac, James, and possibly the Susquehanna rivers in the 1934-35 and 1936-37 cycles would have been most favorable for development of successful year classes: the Susquehanna discharge those years was suitably low in summer but lower than the mean in spring (Tables 12-13).

Catch and landings in 1939-40 were higher than any since 1932-33, but declined precipitously in Maryland in 1940 and Virginia in 1941 to a Bay total catch similar to that of 1925 (Tables 2, 7, 8a-b; Fig. 5; Mapp et al., 1941). A moderately strong 1938 year class was evident in the two 1939 Maryland scrape/dipnet indices (Table 8b, cols. 2-3), and the yearly, fall, and fall/spring trotline indices (cols. 6, 15a-d, 12), but was only moderately expressed in three of the four Virginia dredge indices (cols. 13-14, 16-17).

Pearson's (1945, 1948) dredge indices (Table 8b, cols. 13, 14) were based on two different sets of catch data, whereas mine were calculated from one set of data by two different methods. Pearson (1942) reported declines in another set of individual dredge boat catches, 13 to 41% from 1938-39 to 1939-40, with the largest occurring in December 1939. He concluded that the decline was probably because of overfishing prior to December, and that more weight should be given to the 1939-40 indices (Table 8b, cols. 13-14).

It was extremely cold from December 1939 through January 1940, with January reported as the coldest (22.4°F) in Maryland since 1918, a departure of -10.8°F from normal (U. S. Weather Bureau, 1939, 1940; Pearson, 1942). Tributaries of the Bay and the Upper Bay were frozen during January, with a 32.9°F mean SWT at Baltimore with a deficit of -4.6, making it the lowest since 1918 (Table 9).

From January 16-20, the Lower Bay was frozen over or filled with ice. Despite reports by fishermen of numerous dead adult crabs of the 1938 year class (possibly including larger, immature crabs of the same class and a few older adults) found in dredging areas, Pearson (1942) concluded that the four-month decline in the dredge catch (Table 8a, col. 13) was probably "not due entirely, if at all" to the cold winter. This opinion supports the earlier success of fishing on the 1938 year class, but dismisses the mortalities observed in the dredge fishery.

Abrupt declines in landings and catches by all gears were reported in 1940 and 1941 (Tables 2, 7, 8a). Small trotline catches of mature hard crabs in May 1940 (Tables 8a-b, cols. 12, 15a-b, the yearly fisheries of 1940-41), which should have been supported by the 1938 year class, and soft crabs and peelers that were from a late hatch in 1938, were believed by some watermen to have resulted from the cold winter and to subnormal SWTs and excess rainfall in May (Tables 9-10) that could have inhibited movement, feeding and growth (Pearson, 1942). Departures from mean SWTs at Baltimore ranged from -4.6°F to -1.9°F from January through May 1940.

Warm air and SWTs in May and June 1939, and presumably ideal summer and spring discharges in the 1939-40 water cycle should have favored production of a successful 1939 year class (Tables 10, 12-13). Factors that may have interfered with the development of the year class or its survival to 1940-41 are presently unaccounted for, but the plummeting of catch and landings could have been caused by the decline in stock size resulting from the severity of the 1939-40 winter, and possibly the loss of fishing effort at the start of WWII.

Licenses in 1939 and 1940 varied by state and gear type (Tables 5, 15-17), perhaps because trotline fishermen began switching to the use of wire pots for hard crabs, and crab pound nets had been introduced for taking peeler crabs and were replacing crab scrapes. In the early years of their use in Maryland, wire pots were sometimes called traps; crab pound nets were called fykes or traps in Virginia and Maryland. Numbers of potters, pots, trappers, and traps (for crab pounds) (Tables 15-17) are cited, but not their catch.

Crab landings and catch plummeted in 1941 and the winter of 1941-42 to levels not reported since 1925 (although they may have occurred in the non-census years 1926 and 1927) (Tables 2, 7; Fig. 5), with the exception of one scrape/dipnet index (Table 8b, col. 2). Pearson (1942) concluded that overfishing in 1939 led to the decimation of fishable stocks and an "insufficient spawning reserve" in 1940.

The sighting by a Tangier Island boat captain in August 1940 of millions of crabs the "size of chicken lice" in a cove inside a sand bank at New Point Light House, "pouring into the cove through a cut from the Bay," "so many that they made a dipnet black every time the net was dipped into deep holes", was recorded in research notes by Dr. Seawell Hopkins, a blue crab scientist and staff member of the Virginia Fisheries Laboratory at Yorktown in the early 1940's. If the observation date was correctly recalled, the 1940 year class would have been very abundant, and evidence of that strength was recorded in the relatively large Maryland dipnet catch in 1941 (Tables 8a-b, col. 2). However, support of the scrape, trotline and winter dredge fisheries did not occur in the fall of 1941 and the winter and spring of 1941-42 (cols. 3, 6, 12-17).

The waterman's conversation was recorded July 25, 1944. It is possible that the waterman incorrectly recalled the year or that Hopkins misunderstood and recorded the wrong year. The substantial increase in indices of catchability in 1942-43 (Tables 8a-b) could have been due to the huge success and survival of a 1941 year class.

Other explanations may be offered for the small catches and landings in 1941: (1) significantly fewer fishing licenses for all gear were issued in 1941, although calendar and fiscal year numbers were different (Tables 5, 15-17); (2) crab pots were rapidly replacing trotlines in Virginia, but perhaps not on a scale to equalize catch; (3) considerable fishing effort loss occurred as watermen left for WWII military service. Inexplicably, despite the decreases in catch and landings, more Virginia processing house and buyers' licenses were issued.

SWT in April and May 1940 were low (Table 9), summer inflows from the Potomac and James rivers were high in 1940, and spring inflows from the Susquehanna and James low in 1941, which would not have been favorable for development of a 1940 year class (Tables 9, 12-13). In April and May 1941, SWT were relatively warm, and low summer flows were recorded from all three rivers, all of which would have been favorable for development of a successful 1941 year class.

DISCUSSION

Seasonal and annual variations in the geographical distribution of the various life history stages of the blue crab within the Bay are a reflection of specific requirements for reproduction, growth, and survival. Variability in factors such as seawater and air temperatures, salinity, dissolved oxygen, the kind and extent of favorable habitats, the Bay's water supply cycle, and occasional tropical storms, for example, and their combinations, have been suggested as affecting not only distribution but also the size of the stock biomass. However, it is not likely that a varying Bay environment is the sole cause of variability in the Bay's blue crab stock biomass, since part of the life history of the Chesapeake Bay stock is spent on the adjacent continental shelf. While variations in the shelf aquatic environment that might affect zoeal or megalopal survival have not been investigated, some seasonal atmospheric events which affect shelf circulation patterns have recently shown an association with the transport of early life history stages from the shelf to the Bay.

From comparisons of landings and catch reported by calendar year and by state from 1880 through 1940 with records of the crab fisheries from later decades, in which newer and more efficient gears were used over more regions of the Bay, it is evident that the earlier data do not accurately reveal the seasonal and geographic distribution of the stock. For that reason, in the first 60 years of the fishery, estimates of catchability from independently derived data are likely to overstate estimates derived from landings.

For example, the average annual catch per man of soft and peeler crabs in Maryland in 1920 was 10,450 pounds, estimated from the average scrape/dipnet catch per week of 475 pounds over 22 weeks of effort, reported in Sette and Fiedler's Table 7 (note: their Table 7 incorrectly shows the average catch as 471 for 1920, but it is shown correctly for 1919 in their Figure 9).

In federal publications (Lyles, 1967), 744 licensed scrapes caught 2,421 M pounds, and 1,305 licensed dipnets caught 1,416 M pounds (Tables 2-3) in 1920. The combined catch per unit of gear was 3,254 and 1,085 pounds, respectively, for a total of 4,339 pounds by scrapes and dipnets. The ratio of 3,254 to 1,085 is approximately 3:1, from which it can be estimated that 1,305 dipnets produce the equivalent of 435 scrapes. Consequently, from the federal figures, 744 + 435 = 1179 standard scrape units, which caught 4,339 pounds per unit, 41% of Sette and Fiedler's estimate.

Comparisons of scrape, dipnet, trotline, and dredge catch and effort data from independent sources with federal estimates of landings and effort almost always demonstrated that federal landing estimates were substantially smaller. However, that cannot be said for all years because much detail is missing from all sources. Federal reports of fishing effort were probably derived from numbers of licenses issued by states, perhaps modified with reports from federal field agents who interviewed dealers and watermen, but there are no records of the portion of any season that licenses that were issued had been used, if at all, nor of the hours or days spent each week, nor of the number of units of gear used.

Whether collection methods used in federal canvasses of landings and effort from 1880 through 1940 were consistent is unknown. In fact, between the late 1940's and 1960's I observed federal agents collecting some data through interviews, with verbal approximations of landings, not written records. If changes in procedure or interpretation of data were made by independent investigators or state or federal agents, no reports are known that compare older and newer methods, and no appropriate adjustments can be made to catch, landings, and effort data.

The substitution of a new census system by the Maryland Department of Natural Resources in 1981 produced markedly larger estimates of blue crab landings than reported in earlier years. All Maryland landings were estimated to have been increased by a factor of 1.5 to 1.8, between 50 and 70% (Chris Bonzek, pers. comm.). Since seasonal abundance in any year could be affected by environmental conditions, it should be noted that low river discharges occurring in a drought year, such as 1980, would produce a more favorable environment for development of a year class that could contribute to the later large landings, such as from mid-1981 through mid-1982; however, no favorable environmental conditions for 1981 are known that would sustain large landings in the subsequent years.

Data from an independent crab pot catch study conducted from 1968-95 at Calvert Cliffs, Maryland, (Abbe and Stagg, 1996), and landings from the Potomac River have been used to justify the use of the 1981 census method. Although a complete review of those data at this time is not pertinent to this study of the fisheries from 1880-1940, I question the validity of the small mesh used in the study to adequately assess the proportion of large crabs caught. Studies at VIMS testing the effects of pot mesh size on crab catch clearly indicated that small mesh pots caught substantially fewer large crabs, that very large mesh pots retained very few small crabs but also retained many fewer legal-sized crabs (Pers. obs.). The smallest mesh we used was larger than the 25 mm mesh used by Abbe and Stagg. It is unfortunate that the investigators did not use a "standard" 1½ inch hard crab mesh for their study.

Changes in canvassing procedures may demonstrate increases or decreases in landings or effort, which portray greater success of the fisheries or a serious decline in abundance of the stock, any of which may or may not be true. Differences between landings and catch data between 1880 and 1940 were cited earlier in this report as to which set, if either, could provide accurate estimates of the stock biomass.

Substitution of a different censusing system by the Virginia Marine Resources Commission in 1993, without making a simultaneous and comparative survey, has yet to be tested. By early 1996, Virginia had not published catch/landings data for 1993 or any later year, nor stated whether the newer censusing system reflected any increase or decrease in catchability of the stock.

Watermen probably choose crab fishing sites for their concentrations of particular crab growth stages that seek preferred habitats, and where crabbing gear is effective. Concentrations of adult female hard crabs in the southern end of the Bay in winter, attributed to their physiological response to temperature and salinity, encouraged harvesting by Virginia dredgers, at least by 1900. The intensity of the soft and peeler crab fisheries in Maryland and northern Virginia, and in the middle and upper reaches of some of Virginia's tributaries, may be attributed to wherever juvenile crabs are abundant, due to the physiological response of juveniles to the mid- and low-salinity environments, availability of extensive acreage of shallow-water habitats with substantial food supplies, whether in SAV or marshlands or other bottoms, and where scrape, dipnet, crab trap (crab pound net) fishing would be productive and safely done.

While larger catches and landings of soft and peeler crabs have been and still are reported in Maryland waters than in Virginia, whether there are more juvenile crabs in Maryland than in Virginia is not known. It can be conjectured that given the earlier development of the soft and peeler crab fisheries in Maryland, it became a traditional work ethic. Less interest in the soft and peeler crab fishery in Virginia might be ascribed to less acreage of suitable peeler crab fishing sites, perhaps to smaller numbers of soft and peeler crabs, but also to the Virginia waterman's traditional preference for hard crab fishing. Whether hard crabs were and are now equally available to all Bay watermen in most years cannot be determined from catch or landings data.

Catch is determined by the availability of the fishable portions of the stock and by the efficiency (catchability) of each gear type. Differences in the seasonal, geographic, and age distributions of the stock in the Bay and its tributaries require different types of gear and intensities of fishing effort. Such differences severely complicate statistical analysis.

Further, the collection and compilation of catch and landings data on an annual, calendar year, basis complicates an understanding of the variations in catchability, because those data are comprised of at least two and perhaps three year classes. Catch and landings data must be apportioned to specific year classes when estimating catchability indices. During the normal three- to four-year life span, specific size and age groups are available on a 12-month Biological Year that is not concurrent with a calendar year.

Analysis of the effectiveness of each gear type, useful in determining the apportionment of stock to each fishery and in enacting legislation and regulations governing them, could be approached by designating the three major fisheries as single stocks: (1) scrapes, dipnets, peeler pots, and crab pound nets (traps) for soft and peeler crabs; (2) trotlines and pots for hard crabs; and (3) winter dredges for hard crabs.

For each fishery, one standard unit of effort could be calculated. Indices of catchability, the success of fishing of any standard unit of effort on a year class of crabs, could be related to a base year index, giving a useful picture of long-term trends in stock biomass.

Smaller landings of hard crabs in Maryland than in Virginia (excluding the Virginia winter dredge fishery) in 1920, 1924, 1925, 1929, and from 1934 through 1941 have never been satisfactorily explained. Whenever canvasses of effort or listings of licenses were made, there were usually more trotline, scrape and dipnet crabbers in Maryland than in Virginia, which could (should?) have resulted in larger landings in Maryland.

Considering only the years beginning with 1920, conceivably fewer crabs occurred in many or most years in Maryland than in Virginia, perhaps resulting from variations in environmental quality that affect the distribution of the stock. Even if catchability indices were similar in the two states, which cannot be determined in the absence of better effort data, larger total landings in Virginia could be attributed to a longer fishing season.

Excluding the Virginia winter dredge fishery, the hard crab fishing seasons were of different lengths in the two states: approximately 35 weeks, from April through November, in Virginia, and 23 weeks in Maryland, from May to early October—longer in Maryland if November was added.

In both states, legislative action limited crabbing seasonally and geographically, and sometimes by gear, size of crab or biological condition, i.e., sponge crabs, which eliminated any consistency in the length of the fishing season. The crabbing season was also limited by the seasonal availability of crabs to gear, usually controlled by SWTs, salinities, and bottom types, individually or in combination. Limitations on crabbing from many sources have been extensively reviewed in earlier sections.

The acknowledged common link between the two states in their contributions to the life history of the Bay blue crab is the controlling argument for joint legislative action to promote and sustain the two states' crab fisheries. However, differences between Virginia and Maryland in their political and sociological environments, as well as in the aquatic and atmospheric environments in the two geographic parts of the Bay, may strongly, but predictably, have different effects on the successes of the two states' crab fisheries.

Biomass estimates of the juvenile and adult portions of the crab population probably should be made separately from each state's landings and/or catch data. Virginia's data may potentially be more accurate, since the various gears are used over the entire year and range across all salinities and over almost the entire spectrum of preferred crab habitats. The shorter fishing season, limits on gear use, and a narrower range in variety and quality of preferred habitats in Maryland predictably results in incomplete sampling of the population.

Soft and peeler crab landings reported in Virginia for many years, at least through 1992 before the implementation of a new canvassing system, may have been accurately reported, but unquestionably grossly underreported the actual catch. Sales (= landings) probably represented only 20-70% or less of the catch (Van Engel, pers. obs.). A major unresolved problem is the considerable difference between initial catch, which is not reported, and sales, since the latter does not reflect after-catch mortality. Poor water quality, e.g., low DO, abrupt changes in salinity at fishing sites and in shedding tanks, careless handling by watermen, and blue crab diseases such as *Paramoeba perniciosa*, all contribute to stress on the crabs, and are factors affecting mortality rates.

While deaths of juveniles in the wild probably result from similar factors, as well as cannibalism and predation, and are known to reach 100% in catastrophic events, normal rates in the wild are largely unknown. As long as soft/peeler data remain unreflective of actual catch, they should not be used in population size estimates, nor can they provide an early forecast of the success of the hard crab fisheries.

The suggested cause of the plummeting bay catch between 1907 and 1912 is large landings by the soft/peeler fishery prior to 1912—over 9.5 M pounds in 1908 (over 38 M crabs), plus the untabulated but reported capture of small crabs for soups and stews when no minimum size limits existed in either state. In contrast, minimum size laws enacted in 1912, 1915, and 1916 may have been responsible for peak landings in those and later years. Examples are drafted to consider what the Virginia soft/peeler catch might have been, assuming underreporting and after-catch mortality. In lieu of other estimates, 70% will be used for maximum underreporting, and 50% for after-catch mortality, with lower rates of 50% and 30%, respectively, for a second estimate. More accurate reports might result from the new canvassing system initiated in Virginia in 1993.

Virginia mean landings of soft/peelers for the three years from 1990-92 was 0.93 M pounds, estimated to be comprised of 3.7 M crabs (four crabs/lb), about 2.4% of the mean 39.3 M pounds for combined hard, soft/peeler crab landings. That such a small percentage of the stock of crabs available was harvested as soft and peeler crabs in recent years gives credence to the belief that some of the soft/peeler crab catch was unreported.

If sales were underreported by 70%, the actual peeler sales would have been 3.1 M pounds (12.4 M crabs), 3.33 times that reported. Catch needed to produce 3.1 M pounds, adjusted for a 50% after-catch mortality, would have been about 6.2 M pounds (24.8 M crabs). If the smaller rates are used, total sales would have been 1.86 M pounds (7.44 M crabs), 2.0 times that reported, with an estimated initial catch of 2.66 M pounds (10.64 M crabs). Currently, given assumed catch and after-catch mortality rates, a substantially larger soft/peeler fishery is unknowingly being supported.

Considerable financial gain would have been recognized in the current soft/peeler fisheries with more accurate reporting. The Virginia soft/peeler crab value per pound has been five times or more than the value of hard crabs for over 20 years; in 1992 it was $2.69, compared with $0.39 for hard crabs. Assuming that those returns existed for the entire three years, the soft/peeler fisheries would have returned $2.5 M and the hard crab fisheries $15 M. With 70% underreporting, and omitting after-catch mortality estimates that would not be counted in sales, Virginia's three-year mean soft/peeler landings of 3.1 M pounds (12.4 M crabs) would have been worth about $8.3 M at 1992 value, 3.33 times the reported value. Assuming 50% underreporting, landings of 1.86 M pounds (7.44 M crabs), would have been worth $5.0 M, a 200% increase.

Strict laws limiting the catch of juvenile crabs may be sound management if the intent is to permit more of them to attain maturity and maximum weight and recruit to the hard crab fishery. Limiting the catch would also be a sound management practice in forcing watermen to recognize and prevent the large losses of peelers occurring after capture. Losses could be substantially reduced by more carefully selecting only late stage peelers, e.g., pink or red sign crabs. The claws of "white sign" and "hairline" crabs are usually broken ("nicked") to prevent the crabs from mutilating other crabs in the shedding tanks, and broken claws and mutilations often lead to high mortality rates.

Alternatively, protection of all juveniles would deny watermen a substantial financial return that can be derived from the soft/peeler fishery. From 1887-1901, 72-81% of the combined Virginia and Maryland watermen's income from crabbing was derived from the soft/peeler catch that made up 33-52% of all crabs landed. In Virginia, 48-56% of income came from 15-21% of landings. Later, from 1925 to 1940, 30-35% of the bi-state crabbers' income came from soft and peeler crabs that comprised approximately 10% of all crab landings; Virginia's 16-34% of income came from 5-9% of landings.

Three opposing management strategies may be considered: (1) to expand the soft\peeler fisheries; (2) to eliminate the soft/peeler fisheries, permitting all crabs to mature and thus expand the hard crab fisheries; and (3) to allocate portions to both soft/peeler and hard crab fisheries. Allocation must ensure that the talents of the watermen, their expertise with specific gear, and knowledge of fishing sites are not lost or diluted. It must also permit profitable exploitation of both juvenile and adult portions of the stock, and most importantly, save an adult breeding stock of such magnitude that it presumably could sustain the Bay population of blue crabs indefinitely.

Assuming a 25% expansion of the soft/peeler landings, and accepting the concepts of maximum and minimum adjustments described above, the soft/peeler catch would have to have been 7.75 M pounds to support sales of 3.67 M pounds, valued at $10.4 M, a 316% increase. With smaller adjustments, a 2.3 M lb catch would be needed to support sales valued at $6.2 M, a 248% increase. With a 50% increase in the fisheries, soft/peeler landings would be 9.3 M pounds valued at $12.4 M, a 396% increase, and 2.8 M pounds valued at $7.5 M, a 200 % increase.

Economic gains to expansion of the soft/peeler fisheries would result in losses to the hard crab fisheries. Following a 25% increase in harvesting of soft/peeler crabs and the natural mortality loss that would have occurred in growth from the juvenile to the adult stage, hard crab landings would fall from 38.4 M pounds ($15 M at 1992 value) to 34.5 M pounds, valued at $13.5 M, a 10% loss. Using minimum adjustments, landings would be 36.8 M pounds, valued at $14.3 M, a 4.7% loss.

With a 50% increase in the soft/peeler fisheries, hard crab landings would be 33.8 M pounds, valued at $13.2 M, a 12% loss, and 36.4 M pounds, valued at $14.2 M, a 5.3% loss.

The accrual to the hard crab fisheries if soft/peeler fisheries were eliminated is the original mean weight of landings plus the adjustments for underreporting and after-catch mortality of juvenile crabs, but minus an estimated mortality of 50% during growth to the adult stage. Using numbers cited earlier for maximum adjustments, hard crab landings would be increased from 38.4 M pounds by 4.1 M pounds (12.4 M crabs, at three crabs per pound) to 42.5 M pounds worth $16.6 M, an increase in value of 10.7%. With minimum adjustments, 38.4 M pounds would be increased by 1.8 M pounds, 5.32 M crabs, and would be worth $15.7 M, an addition of only $0.7 M, about 4.7%.

It should be made clear that estimates of underreporting and after-catch mortality do not alter the actual weight and numbers that were caught and landed. Only with accurate reports of catch and effort will fisheries managers be able to realistically assess the possible effects of new regulations on stock abundance and the amounts of catch to apportion to the two growth stages, juveniles and adults, to attain maximum catch and equitable income to the two fisheries, and to assure protection for a breeding population of adults. The latter is the most difficult task. Laws and regulations cannot and should not be promulgated until complete canvassing has been achieved to estimate the approximate size of the stock.

Juvenile and adult blue crabs were found in the upper Chesapeake Bay, the Elk River, the Canal, and the upper Delaware Bay during surveys from June through September of 1971 and 1972, several decades after considerable modification of the Canal in 1938 and after 1958 (Miller et al., 1975). It is possible that similar crab sizes could have been found at those sites from 1927 through 1930 and the following 10 years.

Although no estimate of suspended sediment discharge from all sources from March through May 1929 has been made, it might have been similar to that deposited in later storms. Mean annual deposits of sediment from suspended clays and silts in the upper 25-30 km of the Bay in normal years is about 0.7 cm, which is reworked and redistributed by tidal currents and wind waves the rest of the year (Schubel and Hirschberg, 1978).

Tropical Storm Agnes released massive amounts of rainfall over the Chesapeake Bay drainage basin from June 19-23, 1972, entering the Bay on June 21. She caused extensive damage to the Bay's stocks and fisheries, especially the oyster industry. Wind forces were relatively low, ranging from 32 to 49 mph. Peak river discharges from Agnes were estimated to occur (on average) only once in over 100 years. (Chesapeake Bay Research Council, 1973).

Lethal effects of the storm on blue crab stocks could not be estimated and were believed to be limited, but a massive displacement of crabs occurred, five to 15 miles downstream from the usual fishing grounds, and to deeper waters, which resulted in small catches immediately after the storm. Catch did not return to normal until the end of August (Van Engel, 1973). While deposits in the Upper Bay from all sources caused by Tropical Storm Agnes in June 1972 ranged from 10-30 cm (mean 15 cm), larger deposits in the Upper Bay resulted from the runoff in March 1936 from two small storms plus melting of deep snow and ice cover were estimated as 30 cm, twice as large as those from Agnes (Schubel and Hirschberg, 1978).

Parasitism of male and female juvenile blue crabs by the sacculinid barnacle *Loxothylacus texanus*, frequently reported from the Gulf of Mexico, effectively interrupts growth and development toward their sexually mature stage (Reinhard, 1950; Charniaux-Cotton, 1960; Overstreet, 1978, 1983; Perry et al., 1984). In a summary of the occurrence of the sacculinid on blue crabs in the Gulf of Mexico, Perry et al. (1984) reported peak abundance in months of high temperatures, at high salinities in inshore waters, an intolerance of low salinities, and increasing percentages of parasitized crabs in coastal waters throughout the Gulf in the last two decades. Prevalence may range from less than 1 to over 50 %.

Overstreet (1978) thought that small (dwarf, button-sized) crabs that appear seasonally in Mississippi Sound may have been infested with sacculinids, and noted that the subject needed further attention. Although *L. texanus* has not been found in Chesapeake Bay blue crabs, the accidental introduction of infested crabs could produce a sub-population of small-size male and female crabs that may be incapable of further growth and reproduction. Adult female blue crabs ranging from 50-90 mm LCW have been found in Chesapeake Bay in the last 50 years and none has had an external sacculind sac, but no attempt has been made to determine whether any had an internal infestation (pers. observ.). Cold winter temperature and/or low salinity may inhibit or prevent the sacculinid from being established in the Chesapeake Bay.

The parasite invades the male androgenic gland (which are not the gonads), inactivates its hormones and feminizes the male, altering the shape and structure of the abdomen and the pleopods, but does not destroy the gonads. Infestation of juvenile females, which have no androgenic gland, also results in cessation of growth, modifying the shape of the abdomen to approach that of the adult, atrophying the inner ramus of the pleopods and suppressing yolk deposition (Charniaux-Cotton, 1960). Molting of blue crabs with externa was reported but thought atypical by Overstreet (1978).

Bay environmental conditions have not prevented another sacculinid, *Loxothylacus panopaei*, from becoming established in the Chesapeake Bay. Infestation of a xanthid (mud) crab, *Eurypanopeus depressus*, was first found in November 1964 in the York River (Van Engel et al., 1966), and subsequently in 1965 in *E. depressus* and another xanthid *Rhithropanopeus harrissi*, in all the Virginia rivers on the western shore of the Bay, except those north of the Rappahannock River, and in 1966 in all Virginia tributaries on the eastern shore of the Bay, but none on the ocean side of the Eastern Shore (Daugherty, S. J. 1969). None was found at salinities < 6 ppt). Rarely was a crab found with a scar on the abdomen, suggestive of the loss of an externa. One scarred female *E. depressus* molted four months after collection, did not increase in size and the endopod parts of all four pleopods were reduced. Two and one-half months after the externa of a male was cut off, the crab molted and grew from 11.6 to 12.5 mm LCW, had one normal male pleopod on the first abdominal segment, two female pleopods on the second segment and one female pleopod on the fifth segment. Daugherty concluded that the degeneration or modification of the pleopods would have prevented the male from successful copulation and the female from retaining extruded eggs.

Relationships between environmental factors and their effects on blue crab life history stages have been postulated: (1) whether very warm waters in the spring, May for example, would be favorable for the preparation of the female reproductive system for maturation and extrusion of eggs; (2) whether very warm waters in May would spur early feeding and rapid growth rates of juveniles of the latest (youngest) year class; (3) whether certain phases in the water supply cycle of the Bay, such as low summer/fall and high spring discharges are favorable for the hatch and survival of zoeae and the development of megalopae and juveniles; and (4) whether low water temperature and heavy rainfall in the spring delay the crab fisheries.

A variety of environmental factors must exist that influence biological conditions that establish year class strength, growth and development, and physical factors, such as suitability of habitats and the availability of the stock to fishing gear that determine fishing success. Extreme variations in those factors are more likely associated with extremes in yearclass strength and fishing success. Only when accurate catch and landings data are available for times preceding and succeeding the occurrence of any of those events can the degree of association be determined.

The disparity between about half of the independent surveys of catch and federal (and state) canvasses of landings has not been explained and needs intensive study.

Parent-progeny Relationships

Two studies in which estimates of spawning stock and their progeny in Chesapeake Bay were compared, reported that at the levels of abundance prevailing at that time the magnitude of the parent stock was not a significant factor in establishing progeny abundance.

Hopkins (1946) reported no correspondence between the average daily catch of Virginia patent-dip trotlines during the spawning season (June-August) and the average daily catches of Virginia dredge boats the second winter following, for the 12 years beginning with the summer of 1934 and concluding with the winter (December-March) of 1945-46. Landings by the two hard crab fishing gears were compared graphically, not statistically.

Pearson (1948) reported that little of the variation in progeny abundance was accounted for by parent stock levels ($r = 0.134$), comparing the Virginia winter dredge fishery landings one year with the dredge landings two years later, for the 15 winters of 1931-32 through 1945-46. To make the comparisons, the relative index of fishing success by dredges in 1931-32 was assumed to be an index of female spawners in the summer of 1932, and the index for the winter of 1933-34 was assumed to be a measure of their progeny.

In a study similar to that of Pearson's in that it was based on winter dredge fishery data, Applegate (1983) made use of the Leslie and Davis (1939) method of analysis to obtain spawner/recruit abundance estimates over the 50 year period 1932-81. Applegate reported that 40 to 44 % of the variation in recruitment, relatively large values, could be attributed to parental stock size. The results were obtaining by applying two stock-recruitment models, $R = Se^{(S_r-S)/S_m}$ ($r^2 = 0.40$)(Ricker, 1954), $R = aPe^{-BP}$ ($r^2 = 0.441$)(Ricker, 1958, pp. 282-283).

The Leslie-Davis estimate of standing crop at the beginning of the fishery, December 1, was used as the measure of abundance of progeny that survived from spawning one and one-half years earlier. The difference between the standing crop and the cumulative winter dredge catch over the next four months was an estimate of the survivors at the end of the dredge fishery, March 31, and assumed to be the spawning stock size in the approaching summer.

The methods used by Applegate required assumptions of negligible rates of recruitment, natural mortality, immigration and emigration during the fishing season. Significant rates would result in errors in calculating initial stock size and cumulative catch, and hence estimating the spawning stock size. None of the assumptions appears to have been violated.

The analysis contains two flaws that provide uncertainty as to the accuracy of Applegate's results. In the least squares regression analysis of the daily vessel landings, Applegate did not consider inconstant catchability as a serious factor in most years. Actually, dredges are never equally distributed over the crab population and local reductions in stock are produced. One or more times during the 4-month fishery, effort is directed to new sites, usually following a severe cold wave and a decrease in bottom water temperature, which watermen believe induces crabs to form new aggregations. Because shifts to new sites are likely to be abrupt, occurring over a period of a few days or a week, with concomitant increases in the daily catch, they can be easily identified. Separate linear regressions can be calculated for each period that was initiated with an obvious increase in catch per unit of effort (CPUE). The estimate of the sample cumulative catch (Kt) can be obtained from the intercept on the X-axis of the last regression line.

Also, since dredging sites can be considered the equivalent of geographical subdivisions of the stock, each with its own stock density, combining estimates of the sample cumulative catch for each area could give an estimate of the total Bay catch. The effect of ignoring or not recognizing shifts in catch produces too large an estimate of cumulative catch and too small an estimate of catchability.

Because Applegate's records were obtained from only a portion of the vessels dredging any day or season, the sample's cumulative catch was adjusted by him to approximate the catch of the entire fleet of vessels by multiplying by the ratio of total licenses to the number of vessels sampled. However, Applegate incorrectly applied licenses issued by the Virginia Marine Resources Commission (VMRC) for fiscal years ending June to the dredge season which began the following December 1. Since he offset licenses one year, his ratios of licenses/vessels-sampled are incorrect, and when used in adjusting the sample cumulative catch produce overestimates or underestimates of the total cumulative catch.

Applegate acknowledged that the estimate of the fishery's total catch "sometimes" exceeded the total winter fishery landings, and ascribed that to the unavoidable incomplete sample of the catch. The error from that source is negligible compared with the overestimate produced by ignoring inconstant catchability. Actually, 69% of the estimate of total cumulative catch reported by Applegate exceeded total winter landings reported by Van Engel and Harris (1983) over 49 years, 1931 through 1980.

Until the dredge fishery data can be re-examined, confidence must be withheld from Applegate's estimates that 40-44 % of the variation in recruitment could be attributed to parental stock size.

Management of the Chesapeake Bay blue crab fisheries should be concerned with six main objectives: (1) optimum utilization of the resource leading to near maximum production; (2) a reasonable economic return based on an adequate catch per unit of effort; (3) orderly fishing, in which conflicts between units and types of gear are reduced; (4) recognizing, establishing, and preserving critical habitats; and (5) the abatement and control of pollution.

These objectives cannot be obtained without (6) accurate reports of catch and landings of hard crabs and soft/peeler crabs, the locations of the catch, counts of units of fishing effort for each type of gear, and estimates of the economic return. Achievement of optimum utilization of the resource, a reasonable economic return to individual fishermen, and orderly fishing, may require limited entry; however, quotas on catch and seasonal limitations may be added but not substituted for it.

Year Class

The identity of each year class is established when egg extrusion and hatching of the eggs occurs, and its identity continues through the subsequent development to zoeae, megalopae, juveniles, and adults. Recognition of each stage and the year class to which it belongs can be determined by timely field collections and/or the examination of independent or commercial catch (Fig. 3).

Environmental variables may affect any physiological or physical state of a crab, at any time in its life history, such as maturation of the reproductive organs, growth, distribution, maturity, reproduction, longevity, and mortality and also affect the availability and catchability of blue crabs to fishing gear. Occasionally some variables, such as salinity or its counterpart river discharge, or the abundance and distribution of eelgrass, or atmospheric events influencing the continental shelf currents and the transport of megalopae to the Bay, may be the most important one(s) determining the success of a year class. Awareness of those variables and their affects may aid in identifying possible causes of variations in distribution and abundance of the stock that cannot and should not be explained as the result of laws and regulations on the quantity and quality of the catch.

Annual returns of Bay catch and landings have been used in the data analyses presented so far to the Technical Committee and the Bay Commission. Those analyses have denied the ability to review whether the seasonal abundance in any year or years could have been affected by environmental conditions. Two strong year classes were produced in the Bay-wide drought years of 1980 and 1995, which resulted to significantly large landings in 1981 and part of 1982, and in 1996 and part of 1997, that cannot be attributed to a change in censusing procedures or laws or regulations. The decrease in eelgrass apparent in 1972 has been ascribed as the factor leading to the decline in crab abundance.

Other notable drought years have occurred: 1930, 1941, 1965, 1969, 1995, and possibly a severe one in 1997.

EXECUTIVE SUMMARY

Landings, Catch, Gear, Legislation, and Environmental Data

I. Early development of the fisheries, 1880-1916

Federal censuses were infrequent; only some of them included gear and landings by gear. Bay annual landings rose erratically and reached a peak in 1915, which was not to be duplicated until 1929. However, mean weekly catch by winter dredges and the annual (spring through fall) trotline fishery, reported by independent investigators, decreased gradually from 1907-08 through 1916-17. The annual trotline catch estimates for 1915 and 1916, derived from Virginia watermen's catch, were the smallest of the 10 years beginning in 1907, which raises the question of accuracy of landings data.

Until 1912, immature crabs were probably overharvested to essentially supply the soft crab industry, but also for sale to crabmeat picking houses and to make soups. This would have reduced a substantial portion of the stock that otherwise would have recruited to the hard crab fisheries. Virginia enacted a minimum width law of 3.5 inches on hard crabs other than peelers in 1912, when none previously existed.

In a special federal survey in 1915, the 1912 landings were estimated as larger than those of either of the census years 1908 or 1915, although no firm numbers for 1912 were reported. It is possible that the minimum size law, if honored by the industry, would have resulted in a marked increase in the supply of large hard crabs in 1912.

Commissioners and legislators must have been more convinced of the reports by watermen than by the federal canvass that the catch of crabs had been declining for several years. Early in 1916, the states set a closed season on sponge crabs: July and August in Virginia, and year-round in Maryland. The states also set a minimum width of five inches on hard crabs, which may have caused a reduction in the catch that year, though the new size minimum was limited in Maryland to Somerset County. Infrequent federal censuses for landings and gear usage, and the states' piecemeal licensing of specific gear prevent any reliable analysis of the relationship between fishing effort and landings or catch.

Licensing and a fee to use scrapes in Virginia was first required in 1898, followed in 1900 by a general license for nets or other like devices. Specific licenses for other gears were not required until 1910. In Maryland, peeler crab scrapes may have been first licensed in 1902—it not clear whether one may have been required earlier—and no other licenses were required until 1916 when a general license for any gear was established.

Principal gears used in the 36 years were scrapes and dipnets for soft and peeler crabs, and ordinary trotlines for hard crabs in both states, and the Virginia winter dredge for hard crabs.

Environmental conditions, whether favorable or adverse, were seldom reported; only a few can be used to explain their possible or probable effects on stock abundance or catch. Record or near record low air and SWTs were reported in five winters through 1907, during a 27-year period when only occasional landings surveys were made and in which catch data were collected only in the last year. A small catch in 1902 was credited to mortalities caused by the severe cold winter of 1901-02. The lowest SWTs in May of any year was 56.4°F at Windmill Pt. in 1907.

The winter storm of January 5 to February 16, 1912, was reported as one of the most severe on record in duration and intensity, causing large quantities of ice to form in the Bay and tributaries. Following the storm, the 1912 annual trotline catch increased over that of 1911, and was the largest since 1908. The sequence of a severe winter storm in 1912 and an increase in the trotline catch suggests that a winter storm may selectively destroy the larger and older crabs, which represent only one of the two year classes co-existing.

Ten water cycles favorable for the development of successful year classes occurred from 1893-94 through 1913-14. Five of them occurred between 1906-07 and 1913-14, when catch indices were relatively high.

The combination of excessive rainfall and low SWTs in April has been suggested as causing the delay in the opening of a fishery. According to many watermen, opening of the spring peeler fisheries occurs during the full moon after the third week in April at about the time when SWT reaches 60°F (roughly 16°C), which varies from late April to early May.

May mean air temperature, assumed to be close to SWT at that time of the year, was never below 60°F in Virginia in the 36 years, and only in 1907 in Maryland. May mean SWT at Windmill Point was below 60°F 12 times between 1882 and 1916, but in May 1912 was the third warmest to that date. Excessive rainfall, i.e., > 2.00 inches, exceeded the May means (3.71 in and 3.50 in) only twice in Virginia and once in Maryland, but not during the years when Maryland's air temperatures were < 60°F; it occurred only once in Virginia when the SWT was < 60°F.

II. Period of minimum size and partial sponge crab protection laws, and unfavorable environmental conditions, 1916-26

Federal surveys that included units of gear and landings by gear were made in 1920 and 1925, and a survey of only landings was made in 1924. Landings in 1920 were as low as those reported for 1901, and increased only slightly in 1924 and 1925. Catch data are available for every year through 1926. Scrape/dipnet, trotline, and dredge catches were irregular in the 11-year period, often differing between gears, peaking for all gears in 1922-23 and falling to a new low in 1925-26. Calendar year trotline catches are inaccurate measures of yearclass catchability because spring/summer and fall data represent two year classes, and 95% of fall/winter constituents are from one year class. As well, data from the fisheries of the two states should not be combined, since the states have different lengths of seasons and bottom habitats, and the waters are of different temperatures and salinities. Fall trotline and fall/spring trotline catch indices were the most reliable measures.

In 1917, Maryland's 5-inch width cull law on hard crabs was extended from Somerset County to the entire state, and a soft and peeler crab size limit of three inches was enacted. Virginia imposed a 3-inch minimum size limit on soft crabs in 1922. Sponge crab protection during July and August in Virginia was amended in early 1922 to begin June 15, then ordered in March 1926 to cover all waters of the state for the entire year. Immediate positive effects of the minimum size rules on hard crabs and protection of sponge crabs imposed in 1916 and 1917 could not be determined from landings since no surveys were made until 1920, but those changes may have been the bases for later year class successes between 1919-20 and 1923-24. An exponential increase in trotline licenses in Virginia in 1916 and 1917 reflected only a reinterpretation of who was required to obtain a license, not an increase in fishing effort. The patent dip trotline was introduced in Virginia before 1920, but gear numbers were not reported until 1921, and catch was never separated from that of the ordinary trotline. After 1920 the intensity of fishing remained high in both states.

May 1918 was the warmest in Virginia and Maryland between 1891 and 1940, which should have encouraged early summer growth and production of many large crabs beginning in midseason; however, no landings or catch data can support the probability. Unfavorable abiotic environmental conditions that could have resulted in either high mortality of crabs or a delay in movement, feeding, and growth of crabs, or both, seldom occurred in the 11 years; exceptions were freezing SWTs from November through February, 1917-18 and May in 1917, 1920, 1924 and 1925. The so-called "severe" winter of January-February 1922 was not evident from air or SWT data, and was followed by large summer and winter catches not seen since the first decade of the century. While winter storms briefly curtailed fishing effort and caused mortality more evident among adult female crabs than males, there is no evidence in the first 46 years of the fisheries that they had any lasting effect on the stock.

The combination of low summer/high spring discharges seldom happened concurrently in all three rivers in the water cycles between 1915-16 and 1925-26. Years when summer flow was low and spring flow was high or low in the majority of the rivers were 1916-17 through 1919-20, 1921-22 through 1923-24, and 1925-26, all of which were followed by modest catches, except for 1925-26. Catch by all gear was highest from early 1922 through the winter of 1922-23.

Discharge combinations least favorable for the development of successful year classes, with high flows in summer and low flows in spring, occurred in 1920-21 and 1924-25, and were followed by low catches. Air and SWTs in May were lower than the mean in seven or eight of the 10 years from 1916 through 1925, suggesting that spring environmental conditions would not have encouraged early ovarian development or early feeding and growth of juveniles.

III. Total ban on sponge crab capture and possession, 1926-32

Yearly and fall trotline catch data were reported during the entire period, but federal gear and landings surveys were not resumed after 1925 until 1929. Mean yearly and fall trotline catches improved markedly in 1928, trotline catch peaked in 1930-31 and dredge catch peaked in 1931-32. Unprecedented large landings were reported from 1929 through 1932, peaking in 1930. The sighting of small crabs in the Upper Bay in 1926 and later years after a 10-year absence, and reports of sufficient hard crabs to again support an upbay fishery, suggests that biotic and abiotic conditions favorable to the hatching, growth, and survival of crabs had occurred in 1926 and for the next five years.

The March 1926 prohibition of the capture and possession of sponge crabs from all Virginia waters for the entire year could have protected a larger breeding stock, possibly leading to the production of a large number of eggs and zoeae in 1926. However, not until the spring and summer of 1927 could the effects on stock abundance have been realized by the scrape/dipnet fisheries, for which, unfortunately, no catch or landings data are known. Also, the yearly and fall 1927 trotline catches were small, a continuation of the decline begun in 1925, providing no evidence for any increase in stock abundance from the 1926 hatch. Increases in the minimum size of soft crabs to 3.5 inches in Virginia in 1926 and in Maryland in 1927 apparently had no effect on the 1927-28 yearly and fall hard crab trotline catches: either or both compliance and enforcement were weak or powerless, or the year classes were too small to show obvious increases in numbers.

A precipitous decline in Virginia ordinary trotline, general "crabbers," and scrape licenses began in 1928 for no obvious reason, and dropped lower in 1932 when watermen presumably switched to dipnets during the depression years of 1931 and 1932. Similarly, Maryland "crabbers" licenses plummeted in 1926 from the high numbers of 1921 through 1925, almost to the 1920 level. They remained low until 1930 when they returned to pre-1926 numbers. Maryland trotline and scrape licenses decreased in 1931 and 1932, and dipnet licenses doubled in 1932, presumably in response to the depression.

Licenses for specific gear, including trotlines, were not required in Maryland until 1931, although scrapes had been licensed there at least since 1902. Explanations for the 1926 through 1928 decline in Bay licenses are speculative, perhaps the response to small fishing success from 1924 through 1927. The succeeding big increase in fishing success, in reported landings and catch, occurred at a time when there were relatively small numbers of licensees.

A few explanations are offered for the inconsistency: (1) if fewer but more efficient trotline and scrape fishermen/watermen survived the earlier poor fishing seasons, they could have effected the larger catch per man; (2) larger landings could not have been made as reported if the basis of effort was the number of licensees, therefore there must have been numerous unlicensed watermen engaged in fishing; (3) errors were made in estimating landings, probably by assuming that surveys incompletely canvassed the entire force of watermen, thereby including unreasonably inflated non-existent effort.

Water quality conditions from the summer of 1926 through the spring of 1930 were not considered favorable for the development of any strong year classes: discharges from the Susquehanna and Potomac rivers were high in summers and springs of 1926-27 through 1928-29, while the James River low summer/low spring discharge of 1926-27 would have been favorable for zoeae, but not for juveniles. The marked increase in the Maryland 1928 yearly trotline catch (derived from the 1926 and 1927 year classes) and 1928 fall trotline catch (derived from the 1927 year class), and continued increases in catch in 1929, suggests that factors other than river discharges were increasing the likelihood of success of the 1926 through 1928 year classes.

Water quality conditions did not begin to improve until 1929, and were excellent to good through 1932-33, during which trotline catches were moderate and dredge catches were large. A severe winter storm in November 1929 apparently did not adversely affect the subsequent trotline catch, indicated by the increasing values of the trotline catch indices of 1929-30 and 1930-31.

The combination of excessive rainfall and low SWTs in April 1931 was believed to have retarded growth of crabs in Tangier Sound early that year, and delayed opening of the fisheries, but there is no evidence that the subsequent catch was affected. Construction and operation of the Susquehanna River dams and conversion of the Chesapeake and Delaware canal probably did not alter flow volumes, salinity regimes, or sediment discharges sufficiently to affect blue crab habitats. Acreage of eelgrass plummeted in 1931-32. Effects of the loss of cover, a nutrient source, and reduced stability of the substrate would not be felt until 1932 and later.

IV. Short, open seasons on sponge crabs, 1932-41

Fishing effort was drastically reduced following the August 1933 storm, which destroyed boats, docks, and processing plants, and only slowly recovered in later years. Trotline and scrape use started to expand in Virginia in 1936, but numbers of most gear again began to decrease in 1939. Although licensing for specific gears in Maryland was required in 1931, numbers varied little from year to year until markedly declining in 1941, although dipnet usage declined steadily after 1935. Small numbers of wire-mesh crab pots were introduced in Virginia and Maryland in 1938, undoubtedly replacing other gear.

Landings remained large in 1932 and 1933 and plummeted in 1934, possibly from the loss of eelgrass, the earlier changes in fishing gears, and the loss of boats, docking facilities, and processors in the 1933 storm. They slowly climbed to a peak in 1939 and then plummeted to a low in 1941. All trotline and winter dredge catches were nearly parallel to landings, moderately large in 1932-33, erratic in subsequent years through 1940-41, peaking in 1935-36 and 1939-40, and falling to a new extreme low in 1941-42.

Scrape/dipnet catch was erratic from 1935-36 through 1941-1942. The 1926 year-round ban on sponge crabs in all Virginia waters was amended in 1932 to permit them to be taken from April 1 through June 30, selected because it was a period when sponge crabs were usually scarce. It was further amended in 1934 to prohibit only catching, but not possession. The open season was shortened by one to four weeks each year from 1935 through 1938, but taking sponge crabs the remainder of the year was still prohibited. A 130-square mile sanctuary for adult females in the southern end of the Bay in Virginia was established in 1941.

Severe winter storms of January-February 1934 and March 1936, January 1939, and December 1939-January 1940, were noted in annual reports of Virginia and Maryland commissioners, with comments on crab mortalities during and after each storm reported by Virginia dredgers, and of effects of the storms on fishing effort. The subsequent small spring trotline catch was considered an after-effect of each January storm. River water cycles were often, but not always, more favorable for successful yearclass development in the nine years between 1931-32 and 1939-40 than in the previous seven years, and catch indices by all gears were better.

Warm air and SWT in May in the year of the hatch, and all the variations in the volumes of summer and spring flow from 1931-1932 through 1939-1940 appear to have had a positive effect on the success of the year classes. From 1932 through 1940, May mean air temperatures below 60°F did not occur in Virginia, no SWT below 60°F occurred at Baltimore, only in 1935 was Maryland air temperature below 60°F, and excessive rainfall in May did not occur in either state. In retrospect, May weather from 1932-41 is considered not to have had any effect on early spring catch, nor was any delay in the opening of a fishery reported.

Table 1. Landings in pounds, 000 omitted, 1880-1920. Federal reports, Lyles, 1967.

Cal. Year	Hard crabs		Soft/peelers		State Total		Hard crabs Total	Soft/ peelers Total	Total Bay	Cal. Year
	VA	MD	VA	MD	VA	MD				
1880	2,139	1,167	.	.	2,139	1,167	3,306	.	3,306	1880
1887	627	2,758	.	1,637	627	4,394	3,384	1,637	5,021	1887
1888	956	2,675	.	2,209	956	4,884	3,632	2,209	5,840	1888
1890	2,585	2,388	440	4,056	3,025	6,444	4,973	4,496	9,469	1890
1891	2,208	2,777	586	4,829	2,794	7,606	4,984	5,415	10,400	1891
1897	5,331	5,333	1,068	4,116	6,400	9,449	10,665	5,184	15,849	1897
1901	6,113	9,825	1,288	4,304	7,402	14,128	15,938	5,592	21,503	1901
1904	10,356	12,665	1,911	5,733	12,267	18,318	23,021	7,644	30,665	1904
1908	23,001	12,786	2,082	7,587	25,083	20,373	35,787	9,669	45,456	1908
1915	18,765	22,492	1,484	7,602	20,249	30,094	41,257	9,086	50,343	1915
1916	16,343	21,334	1,234	6,688	17,577	27,972	37,678	7,872	45,549	1916
1920	12,465	5,166	1,172	3,897	13,637	9,063	17,631	5,069	22,700	1920

Table 2. Virginia and Maryland landings by gear, in pounds, 000 omitted, rounded. 1897-1945. Federal reports, Lyles, 1967.

Cal. Year	Dredge	Trotline				Scrape				Dipnet			
	Hard crabs	Hard crabs		Soft/ peelers		Hard crabs		Soft/ peelers		Hard crabs		Soft/ peelers	
	VA	VA	MD	VA	MD	VA	MD	VA	MD	VA	MD	VA	MD
1897	.	5,311	5,116	.	83	.	216	798	3,433	.	.	270	398
1901	.	6,103	9,771	.	268	.	32	995	2,526	.	.	294	1,410
1904	2,210	8,146	12,179	.	135	.	486	1,585	3,938	.	.	326	1,619
1908	.	14,049	11,035	2	.	.	.	.	.	.	.	.	.
1915	4,196	14,043	19,920	.	365	231	1,471	616	3,687	295	1,100	868	3,531
1920	3,069	9,341	4,573	.	17	37	184	819	2,421	19	401	303	1,416
1925	3,999	14,393	6,599	13	68	45	296	437	973	94	426	697	1,264
1929	7,073	21,452	24,013	.	.	1,429	939	1,278	1,611	390	503	422	1,008
1930	7,494	20,113	30,316	.	.	1,024	1,220	1,984	3,200	308	90	897	2,065
1931	7,214	21,355	29,016	.	.	350	538	1,109	2,097	44	377	603	1,726
1932	8,211	18,302	27,072	.	17	69	659	147	631	327	1,669	1,373	2,741
1933	6,555	17,047	25,544	.	.	117	1,016	129	741	193	88	1,939	2,441
1934	5,597	16,862	13,011	.	.	6	607	11	719	47	4	1,360	1,364
1935	4,792	14,686	17,014	.	283	6	243	33	1,102	156	8	1,281	1,054
1936	6,260	19,354	13,229	194	270	29	65	257	1,205	332	.	1,311	673
1937	4,903	22,303	16,051	31	263	74	.	455	1,488	12	148	1,347	701
1938	5,392	22,434	20,529	506	250	280	100	542	1,826	173	50	677	716
1939	4,088	21,002	23,903	435	298	647	113	1,079	2,253	.	27	652	562
1940	3,534	14,129	14,737	450	171	244	33	567	1,284	.	.	435	291
1941	2,117	7,548	11,625	371	156	176	.	395	527	39	.	457	147
1942	2,665	7,954	13,808	311	59	152	40	336	1,325	154	.	358	190
1943	No survey												
1944	2,178	10,256	13,913	384	141	325	25	420	830	32	.	520	104
1945	2,258	2,964	12,234	42	105	6	10	500	923	17	17	425	584

Table 3. Crab fishing effort, number of licenses, 1880-1920. Federal reports, Lyles (1967); Roberts (1905), Churchill (1919a). Data summarized by Van Engel and Harris, 1983.

Cal. Year	Trotline		Scrape Boats (1)		Dipnet		Dredge Vessels (1)		Cal. Year
	VA	MD	VA	MD	VA	MD	VA	MD	
1880	No gear survey								1880
1887	.	.	413	1,403	.	.	.	.	1887
1888	No gear survey								1888
1890	No gear survey								1890
1891	No gear survey								1891
1897	No gear survey								1897
1901	.	1,138(2)	467	1,416	.	2,136(2)	.	.	1901
1904	.	1,138	559	1,328	.	.	11	.	1904
1908	No gear survey								1908
1915	1,139	1,525	134	1,278	641	1,770	106	.	1915
1916	(1,055)(3)	1,661	(3)	532	(3)	894	83(3)		1916
1920	.	.	278	744	867	1,305	59	.	1920

(1) Number of boats or vessels, if cited, otherwise one-half the number of scrapes or dredges.
(2) Roberts, 1905
(3) Combined trotline, dipnet and scrape crabbers, from Churchill, 1919a.

Table 4. Virginia crab licenses, 1899-1920. Virginia Commission of Fisheries reports, compiled by W. A. Van Engel.

Fiscal Year End (1)	Crab-bers (2)	Crab-bers (2)	Hand Trot-line (2)	Hard Crab Scrape (3)	Dredge	Total Crab-bers	Picking Crating Packing (4)	Canner (5)	Buyer (5)	Fiscal Year End (1)
1899(6)	.	.	.	.	.	786	.	.	.	1899
1900	.	.	.	.	.	509	.	.	.	1900
1901	.	.	.	.	.	443	.	.	.	1901
1902	.	.	.	.	.	570	.	.	.	1902
1903	.	.	.	.	.	558	.	.	.	1903
1904	.	.	.	.	.	521	.	.	.	1904
1905	.	.	.	.	.	484	.	.	.	1905
1906	.	.	.	.	.	661	.	.	.	1906
1907	.	.	.	.	.	540	.	.	.	1907
1908	.	.	.	.	.	615	.	.	.	1908
1909	.	.	.	.	-	638	.	.	.	1909
1910	501	7	.	1	.	509	1	.	.	1910
1911	308	194	100	2	18	622	46	1	.	1911
1912	105	172	6	9	13	305	24	.	.	1912
1913	.	244	1	5	34	283	44	?	?	1913
1914	.	328	11	5	46	390	30	?	?	1914
1915	.	197	7	7	61	272	36	1	25	1915
1916	.	1080	.	.	65	1145	45	2	44	1916
1917	.	2541	.	10	70	2621	54	2	?	1917
1918(7)	.	.	.	.	-	.	-	.	.	1918
1919	.	1128	.	19	23	1170	47	1	65	1919
1920	.	1035	.	.	14	1115	45	1	66	1920

(1) The fiscal year begins and ends one month later than the year of record of the licenses, i.e., the report of July 1-June 30 covers licenses issued June 1-May 31. 1899-1923 fiscal year ended September 30.
(2) From 1910-1915 there was apparently a slow changeover from a lower \$1.00 tax to a \$2.00 tax for a crabber's license, and includes soft crab scrapes and dipnets. Trotlines for crabs for canning or picking separately licensed in 1910, but included in crabbers license in 1916.
(3) Sail boats and on power boats under 32 ft length.
(4) Crab meat picking and soft crab shedding houses.
(5) The question mark indicates where numbers cannot be interpreted.
(6) March 1898-September 1899.
(7) No report.

Table 5. Crab fishing effort, number of licenses, 1920-1941. Federal reports, summarized by Van Engel and Harris, 1983.

Cal. Year	Trotline		Scrape Boats (1)		Dip net		Dredge Vessels (1)		Cal. Year
	VA	MD	VA	MD	VA	MD	VA	MD	
1920	.	.	278	744	867	1,305	59	.	1920
1924	No gear survey								1924
1925	.	.	228	474	759	1,159	60	.	1925
1929	1,064	1,408	258	536	405	1,180	62	.	1929
1930	1,386	1,510	256	584	710	1,393	51	.	1930
1931	1,094	1,560	179	539	745	1,776	56	.	1931
1932	994	1,227	30	369	1,349	1,523	63	.	1932
1933	1,075	1,547	42	321	1,675	1,458	65	.	1933
1934	1,437	1,531	4	286	2,391	1,321	105	.	1934
1935	1,304	1,731	8	304	1,966	1,215	127	.	1935
1936	2,140	1,881	47	280	1,495	991	107	.	1936
1937	1,962	1,586	74	296	1,440	863	99	.	1937
1938	1,603	1,766	117	307	954	670	148	.	1938
1939	1,390	1,851	113	274	658	484	91	.	1939
1940	1,269	1,695	36	224	543	449	80	.	1940
1941	844	1,296	40	98	304	341	58	.	1941

(1) Number of boats and vessels, if cited, otherwise one-half the number of scrapes or dredges. No dredges listed for Maryland until 1947.

Table 6. Percentage of hard crab landings by state, season and gear. Dredge (DR), Trotline (TR), Pot (PT).

Calendar Years	Annual					June-September				July-August			
	VA			MD		VA		MD		VA		MD	
	DR	TR	PT	TR	PT	TR	PT	TR	PT	TR	PT	TR	PT
1919-1925	22.8	76.6	.	89.5	.	26.6	.	62.0	.	10.4	.	29.6	.
1961-1970	24.6	5.6	67.9	45.5	53.9	2.6	30.7	34.7	41.1	1.4	16.3	20.1	23.8
1971-1977	20.8	0.5	77.7	37.2	62.3	0.3	38.6	28.9	48.5	0.1	20.7	17.6	29.3

Table 7. Landings in pounds, 000 omitted, 1920-1945. Federal reports, 1967.

Cal. Year	Hard crabs		Soft/peelers		State Total		Hard crabs Total	Soft/ peelers Total	Total Bay	Cal. Year
	VA	MD	VA	MD	VA	MD				
1920	12,465	5,166	1,172	3,897	13,637	9,063	17,631	5,069	22,700	1920
1924	14,462	7,666	622	2,083	15,084	9,750	22,129	2,705	24,833	1924
1925	18,532	7,321	1,422	2,325	19,954	9,646	25,853	3,747	29,601	1925
1929	30,378	25,456	1,700	2,645	32,078	28,100	55,833	4,345	60,178	1929
1930	28,940	31,626	2,881	5,313	31,821	36,939	60,566	8,194	68,760	1930
1931	28,963	29,931	1,712	3,911	30,676	33,841	58,894	5,623	64,517	1931
1932	27,024	29,399	1,549	3,540	28,573	32,939	56,423	5,089	61,513	1932
1933	23,911	26,648	2,068	3,449	25,979	30,097	50,599	5,517	56,076	1933
1934	22,516	13,621	1,370	2,289	23,886	15,910	36,137	3,659	39,796	1934
1935	19,763	17,265	1,449	2,557	21,212	19,821	37,027	4,006	41,033	1935
1936	26,138	13,294	1,970	2,269	28,107	15,563	39,432	4,238	43,670	1936
1937	27,928	16,198	2,475	2,514	30,403	18,712	44,126	4,989	49,115	1937
1938	28,690	20,699	2,783	2,898	31,473	23,598	49,390	5,681	55,070	1938
1939	26,967	24,063	2,783	3,234	29,750	27,296	51,030	6,017	57,046	1939
1940	23,016	15,031	1,977	1,791	24,994	16,822	38,048	3,768	41,916	1940
1941	15,717	11,975	1,710	836	17,426	12,812	27,692	2,546	30,238	1941
1942	18,644	14,048	1,445	1,645	20,089	15,694	32,692	3,091	35,783	1942
1943	No survey									1943
1944	23,929	17,155	1,832	1,112	20,652	18,267	41,084	3,535	44,618	1944
1945	18,820	18,470	1,832	1,700	20,652	20,170	37,290	3,532	40,822	1945

Table 8a. Catch data and indices of catchability. Scrape/dipnet (ScD) and Dipnet (Dip) year after hatch; scrape (Sc) 11 months and 12-15 months after hatch; trotline during year (TrYr), in fall (TrFl), in fall and spring (TrFs); winter dredge (Dr). In pounds/week unless otherwise stipulated. MDt from Tilghmans, MDts includes St. Michaels. [illegible] is assigned base year. Index represents calculation obtained from another author. Da refers to daily means used in calculation. Year class is one year earlier than year cited first in period. Numbers in parentheses refer to footnote sources.

Period	ScD/MD (1); Dip/MD Da (2)	TrYr/VA (4); ScD/MD Index (3)	TrFl/MD Da (6)	TrYr/MD Da (12)	TrYr/VAMD (5); TrYr/MDt Da (15a)	TrFl/MD (7a); TrYr/MDts Da (15b)	TrFl/VA (7b); TrFs/MDT Da (15c)	TrFs/MD (8); TrFs/MDts Da (15d)	TrFs/VA (9)	TrYr/MD (7c); DrVA/Da (13)	TrYr/VA (7d); DrVA Index (14)	DrVa (10); DrVA Index (16)	DrVA (11); DrVA Index (17)	ScVA/Da Index (18)	ScVA/Da Index (19)	Year Class
1906-07												12090				1905
1907-08		2020										12870				1906
1908-09		1580										8970				1907
1909-10		1465										5538				1908
1910-11		1509										5460				1909
1911-12		1166										.				1910
1912-13		1562										.				1911
1913-14		1500										.				1912
1914-15		1118										2828				1913
1915-16		726										3608				1914
1916-17		783										3510	2608			1915
1917-18		928											4165			1916
1918-19													5457			1917
1919-20	471				1169	1133	1167	825	837	971	1307		3113			1918
1920-21	475				729	933	1393	533	1085	622	802		2514			1919
1921-22	628				589	499	1021	449	759	383	784		2920			1920
1922-23	825				803	1662	1040	1220	1196	956	662		8532			1921
1923-24	518				1006	1109	771	896	574	1037	952		4177			1922
1924-25					524		569	358	361	659	398		2528			1923
1925-26			181	100	632		970			642	525	0.30				1924
1926-27			188	144								0.77				1925
1927-28			152	87								.				1926
1928-29			384	238								.				1927
1929-30			406	406								.				1928
1930-31			703	531								.				1929
1931-32			457	369							2.01	2.13	1.008			1930
1932-33			326	362							1.20	1.35	0.69			1931
1933-34			304	238							0.94	0.97	0.51			1932
1934-35			145	119							0.68	0.70	0.39			1933
1935-36		1.008	334	319							0.75	0.83	0.44			1934
1936-37	120	0.83	188	138	162	188	161	354		12.8	0.86	0.93	0.50			1935
1937-38	142	0.77	264	162	169	178	200	442		8.5	0.60	0.70	0.36			1936
1938-39	219	0.91	304	238	278	267	350	641		12.8	0.82	0.93	0.50			1937
1939-40	114	0.92	441	319	366	309	437	578		9.5	0.79	0.85	0.47			1938
1940-41	79	0.39	131	131	124	124	92	233		8.5	0.66	0.71	0.40			1939
1941-42	126	0.25	44	75	95	89	144	188		4.7	0.37	0.39	0.21			1940
1942-43	69	0.61	428	306	311	300	343	609		19.1	1.60	1.77	0.89	0.30	0.33	1941
1943-44	101	0.32	188	156	167	159				5.0	0.38	0.40	0.21	0.19	0.18	1942
1944-45		0.51	218	144						7.6	0.56	0.64	0.37	0.66	0.49	1943
1945-46		0.68									1.43	1.42	0.73	0.23	0.57	1944

(1) May-October, first year, computed from Sette & Fiedler (1925, Tbl. 7).
(2) May-October, first year, computed from Pearson (1945, Tbl. 1).
(3) May-October, first year, from Pearson (1948, Tbl. 8, I-III combined), base assigned by Pearson.
(4) May-June, Sept-Nov, first year, computed from Sette & Fiedler (1925, Tbl. 1) obtained from Churchill [1917].
(5) May-June, Sept-Nov, first year, computed from Sette & Fiedler (1925, Tbl. 1).
(6) Fall, first year, extrapolated from Pearson (1945, Fig. 2).
(7a-d) Year, fall, first year, computed from Sette & Fiedler (1925, Tbls. 4, 5).
(8) Fall/spring, both years, computed from Sette & Fiedler (1925, Tbl. 7).
(9) Fall/spring, both years, computed from Sette & Fiedler (1925, Tbl. 5).
(10) December-March, both years, computed from Sette & Fiedler (1925, Tbl. 1) obtained from Churchill [1917].
(11) December-March, both years, computed from Sette & Fiedler (1925, Tbl. 1).
(12) Year, extrapolated from graph, MD Dept. Res. Educ. (1955), base assigned by Van Engel.
(13) December-March, computed from Pearson, barrels per day (1945, Tbl. 1).
(14) December-March, both years, Pearson (1948, Tbl. 10).
(15a-d) Year, fall and fall/spring, computed from Cronin (1944, Tbls 1-11).
(16) December-March, both years, Van Engel (1951, Tbl. 2) and unpublished.
(17) December-March, both years, Van Engel, unpublished, base year class 1930 = 1.00.
(18) May, Van Engel, unpublished, base year class 1953 = 0.768.
(19) June-September, Van Engel, unpublished, base year class 1953 = 0.768.

Table 8b. Indices of catchability. Scrape/dipnet (ScD), dipnet (Dip), scrape (Sc) 11 and 12-15 months after hatch; annual trotline (TrYr), in fall (TrFl), in fall and spring (TrFs); winter dredge (Dr). MDt from Tilghmans, MDts includes St. Michaels. B is assigned base year. Index represents calculation obtained from another author. Da refers to daily means used in calculation. * Mean Index and No. Cases exclude annual trotlines (TrYrVA, TrYrMD, TrYrVAMD, TrYrMDt, TrYrMDts), and ScDMD, DipMD; ScVAs are included. Year class is one year earlier than year cited first in period. Numbers in parentheses refer to footnote sources.

Period		TrYr VA* (4)										DrVA (10)				Mean Index *	No. Cases *	Year Class
1906-07												1.00B				1.00	1	1905
1907-08		1.00B										1.06				1.06	1	1906
1908-09		0.78										0.74				0.74	1	1907
1909-10		0.72										0.46				0.46	1	1908
1910-11		0.74										0.45				0.45	1	1909
1911-12		0.54										.				.	0	1910
1912-13		0.72										.				.	0	1911
1913-14		0.69										.	DrVA			.	0	1912
1914-15		0.51										0.23	(11)			0.23	1	1913
1915-16	ScD	0.33			TrYr	TrFl	TrFl	TrFs	TrFs	TrYr	TrYr	0.30				0.30	1	1914
1916-17	MD*	0.36			VAMD*	MD	VA	MD	VA	MD*	VA*	0.29	0.21B			0.25	2	1915
1917-18	(1)	0.43			(5)	(7a)	(7b)	(8)	(9)	(7c)	(7d)		0.34			0.34	1	1916
1918-19													0.44			0.44	1	1917
1919-20	1.00B				0.53B	0.54B	0.54B	0.36B	0.36B	0.45B	0.60B		0.25			0.41	5	1918
1920-21	1.01		TrFl	TrYr	0.34	0.44	0.64	0.23	0.47	0.29	0.36		0.20			0.40	5	1919
1921-22	1.33		MD	MD*	0.28	0.23	0.47	0.19	0.33	0.18	0.36	DrVA	0.23			0.29	5	1920
1922-23	1.76		Da	Da	0.38	0.78	0.48	0.53	0.52	0.45	0.30	Index	0.69			0.60	5	1921
1923-24	1.11		(6)	(12)	0.48	0.52	0.35	0.38	0.25	0.48	0.43	(16)	0.34			0.37	5	1922
1924-25					0.25		0.26	0.15	0.16	0.31	0.18		0.20			0.19	4	1923
1925-26			0.29B	0.16B	0.30		0.44			0.30	0.24	0.30				0.34	3	1924
1926-27			0.30	0.23								0.77				0.54	2	1925
1927-28			0.24	0.14							DrVA	.	DrVA			0.24	1	1926
1928-29			0.62	0.38							Index	.	Index			0.62	1	1927
1929-30			0.66	0.65							(14)	.	(17)			0.66	1	1928
1930-31		ScD	1.13	0.85								.				1.13	1	1929
1931-32		MD*	0.74	0.59	TrYr	TrYr	TrFs	TrFs			2.01	2.13	1.00B			1.47	4	1930
1932-33	Dip	Index	0.52	0.57	MDt	MDts	MDt	MDts		DrVA	1.20	1.35	0.69			0.94	4	1931
1933-34	MD*	(3)	0.49	0.38	Da*	Da*	Da	Da		Da	0.94	0.97	0.51			0.73	4	1932
1934-35	(2)		0.23	0.19	(15a)	(15b)	(15c)	(15d)		(13)	0.68	0.70	0.39			0.50	4	1933
1935-36		1.00B	0.54	0.51							0.75	0.83	0.44			0.64	4	1934
1936-37	1.00B	0.83	0.30	0.22	0.26B	0.29B	0.26B	0.71B		1.06B	0.86	0.93	0.50			0.66	7	1935
1937-38	1.18	0.77	0.42	0.26	0.27	0.28	0.32	0.89		0.70	0.60	0.70	0.36	ScVA	ScVA	0.57	7	1936
1938-39	1.77	0.91	0.49	0.38	0.44	0.41	0.56	1.29		1.06	0.82	0.93	0.50	Da	Da	0.81	7	1937
1939-40	0.92	0.92	0.71	0.50	0.59	0.48	0.71	1.16		0.79	0.79	0.85	0.47	Index	Index	0.78	7	1938
1940-41	0.64	0.39	0.21	0.21	0.20	0.19	0.15	0.46		0.70	0.66	0.71	0.40	(18)	(19)	0.47	7	1939
1941-42	1.01	0.25	0.07	0.12	0.15	0.14	0.23	0.37		0.39	0.37	0.39	0.21			0.29	7	1940
1942-43	0.56	0.61	0.70	0.49	0.50	0.46	0.55	1.20		1.81	1.60	1.77	0.89	0.30	0.33	1.02	9	1941
1943-44	0.81	0.32	0.31	0.25	0.27	0.24				0.47	0.38	0.40	0.21	0.19	0.18	0.49	7	1942
1944-45		0.51	0.36	0.23						0.72	0.56	0.64	0.37	0.66	0.49	0.54	7	1943
1945-46		0.68									1.43	1.42	0.73	0.23	0.57	0.88	5	1944

(1) May-October, first year, computed from Sette & Fiedler (1925, Tbl. 7).
(2) May-October, first year, computed from Pearson (1945, Tbl. 1).
(3) May-October, first year, from Pearson (1948, Tbl. 8, I-III combined), Base assigned by Pearson.
(4) May-June, Sept-Nov, first year, computed from Sette & Fiedler (1925, Tbl. 1) obtained from Churchill [1917].
(5) May-June, Sept-Nov, first year, computed from Sette & Fiedler (1925, Tbl. 1).
(6) Fall, first year, extrapolated from Pearson (1945, Fig. 2).
(7a-d) Year, fall, first year, computed from Sette & Fiedler (1925, Tbls. 4, 5).
(8) Fall/spring, both years, computed from Sette & Fiedler (1925, Tbl. 7).
(9) Fall/spring, both years, computed from Sette & Fiedler (1925, Tbl. 5).
(10) December-March, both years, computed from Sette & Fiedler (1925, Tbl. 1) obtained from Churchill [1917].
(11) December-March, both years, computed from Sette & Fiedler (1925, Tbl. 1).
(12) Year, extrapolated from graph, MD Dept. Res. Educ. (1955), Base assigned by Van Engel.
(13) December-March, computed from Pearson (1945, Tbl. 1).
(14) December-March, both years, Pearson (1948, Tbl. 10).
(15a-d) Year, fall and fall/spring, computed from Cronin (1944, Tbls I-II).
(16) December-March, both years, Van Engel (1951, Tbl. 2) and unpubl.
(17) December-March, both years, Van Engel unpublished, base year class 1930 = 1.00.
(18) May, Van Engel unpublished, base year class 1953 = 0.768.
(19) June-September, Van Engel, unpublished, base year class 1953 = 0.768.

Table 9. Departures from long term monthly mean surface water temperature, °F, Baltimore, MD, (2) 1877-1887, (1) 1914-1954, and (2) Windmill Point, Rappahannock R., 1882-1922. Deviations plus unless marked. May deficits, from 60°F, Baltimore >3.3°F or 4.1°F (ca 1.4°C, 1.8°C), and for Windmill Point >2.1°F, 0.7°C, marked with *. Temperature deviations at Stingray Point are recorded in ( ) in absence of Windmill Point data. Freezing temperatures in any month are marked with **. (1) USC&G Survey (1955); (2) Bumpus (1957). Deviations calculated by W. A. Van Engel.

	Dec B	Dec W	Jan B	Jan W	Feb B	Feb W	Mar B	Mar W	Apr. B	Apr W	May B	May W	Jun. B	Jun. W
Mean	40.3	41.6	35.3	37.4	36.6	36.4	41.1	41.0	50.4	50.2	63.3	62.1	73.0	71.9
Period														
1886-87		-0.8	-0.5	-3.1	2.5	2.6	-0.3	0.0	.	-3.6	.	1.3	.	1.0
1887-88		-0.6		-0.2		-1.4		-3.1		-1.4		-0.6		1.7
1888-89		-0.1		3.6		1.7		-0.9		0.4		3.3		1.4
1889-90		5.5		9.3		9.1		3.2		1.3		1.6		4.1
1890-91		1.1		(0.9)		(6.8)		1.2		2.5		-0.1		0.0
1891-92		(2.5)		2.0		1.9		-0.1		-1.3		1.5		2.4
1892-93		-0.4		-6.2**		-2.2		-2.0		-1.6		-0.7		2.1
1893-94		3.0		4.6		3.8		5.4		0.0		2.3		1.2
1894-95		3.4		-0.3		-4.6**		-3.1		-0.1		-3.2*		1.0
1895-96		2.2		0.1		2.7		-1.3		0.3		4.8		2.0
1896-97		1.1		1.7		1.0		2.8		2.7		-0.4		-0.2
1897-98		4.5		2.4		2.3		4.2		-1.8		(-5.6) Error		-0.5
1898-99		0.1		1.8		-2.8		-0.5		-0.3		0.0		4.5
1899-00		3.4		1.9		-1.7		-3.4		-3.5		-1.1		0.2
1900-01		-2.3		0.5		-1.9		-2.9		(-0.9)		(-0.9)		0.5
1901-02		2.4		-2.5		-5.0**		-1.8		-2.4		(3.6)		(0.1)
1902-03		(3.3)		-1.0		0.3		2.9		1.0		-1.9		-3.2
1903-04		-3.3		-4.4		-4.9**		-3.6		-3.1		0.0		0.8
1904-05		-2.8		-2.7		-5.4**		-2.1		-2.6		2.9		-1.3
1905-06		1.3		2.8		-0.5		-2.1		-1.5		-0.5		0.0
1906-07		0.3		2.4		-2.6		-0.8		-4.7		-5.7*		-9.0
1907-08		-1.3		0.2		(-3.7)		2.6		3.9		2.4		-0.2
1908-09		-0.4		0.1		5.2		0.0		4.3		-0.2		2.4
1909-10		-5.0		(-4.4)		(-3.3)		2.0		0.8		-2.3*		-6.3
1910-11		-7.0	**Mean**	1.7	**Mean**	1.8	**Mean**	1.6	**Mean**	-0.2	**Mean**	7.1	**Mean**	1.9
1911-12	**Mean**	-0.8	37.5	(-5.1)	37.0	(-5.9)	42.6	-0.9	52.7	6.4	64.1	3.6	74.0	-0.5
1912-13	42.9	-0.0		4.4		1.2		6.4		3.6		0.9		2.3
1913-14		0.6	-1.0	1.5	-2.3	-0.1	-5.4	-3.9	-1.8	-1.9	1.6	2.1	0.8	1.0
1914-15	-2.8	-0.2	-1.2	-1.0	0.2	1.0	-1.8	-1.3	1.6	-2.0	0.7	-0.7	-1.3	-3.1
1915-16	-2.8	-1.1	-1.7	-0.1	-0.5	1.0	-6.5	-4.1	-3.6	-2.7	-0.6	0.3	-2.4	-1.2
1916-17	-1.0	0.4	-2.8	-0.6	-4.5	-2.2	-2.7	-1.2	-0.9	-1.1	-5.8*	-3.8*	-0.4	-2.0
1917-18	-5.7	-5.3	-5.7**	-7.5**	-3.6	-4.6**	-0.2	1.5	-2.5	0.6	2.3	1.5	-0.6	-0.8
1918-19	1.5	2.7	0.3	0.8	1.5	1.5	2.7	3.5	-0.9	-0.3	-0.8	-0.6	3.0	0.3
1919-20	-1.5	-2.0	-4.4	-5.0	-3.7	-3.3	-3.2	-3.3	-1.1	-1.6	-3.3*	-4.2*	-2.2	-2.1
1920-21	1.0	1.6	-0.3	0.9	1.3	1.1	7.4	6.3	6.3	5.2	-0.8	-1.3	0.8	-0.7
1921-22	0.3	1.2	-2.8	-3.0	-1.2	-2.6	0.6	-0.2	2.0	1.5	2.1	-0.1	1.9	-0.3
1922-23	-1.2		-0.1		-2.1		-1.8		-2.2		-1.0		1.2	
1923-24	3.1		-0.8		-1.8				0.7		-2.9		-3.5	
1924-25	-1.9		-3.0		0.2		1.3		2.3		-2.0		3.0	
1925-26	-1.0		-3.5		-2.7		-3.9		-3.8		-1.5		-4.6	
1926-27	-3.2		-2.8		0.8		2.2		-1.6		-2.2		-3.7	
1927-28	0.6		-1.9		-1.2		-1.4		-1.8		-2.2		-3.1	
1928-29	0.8		-0.5		-1.8		1.5		2.2		-0.2		0.1	
1929-30	-2.6		0.3		1.5		1.3		-1.6		1.4		0.7	
1930-31	-2.3		-1.5		0.9		-0.7		0.2		-0.4		-0.2	
1931-32	5.7		7.3		5.1		-1.8		-1.6		0.5		-0.2	
1932-33	-1.0		3.9		1.5		-0.9		0.5		0.7		0.8	
1933-34	-1.7		0.1		-4.6		-5.4		-1.3		-0.2		1.7	
1934-35	0.4		-1.2		-1.9		1.8		-2.2		-2.6		-0.6	
1935-36	-1.9		-3.2		-4.5		0.2		-1.6		3.0		-0.1	
1936-37	-1.5		5.1		2.4		-1.1		-1.6		0.7		3.0	
1937-38	-1.4		0.6		2.2		1.3		1.6		0.3		1.2	
1938-39	0.8		1.0		1.8		1.1		-1.1		0.7		2.3	
1939-40	1.0		-4.6		-1.9		-3.8		-4.3		-1.9		-0.1	
1940-41	0.4		1.2		-0.5		-4.1		2.7		-0.4		-1.0	
1941-42	4.0		0.4		-1.2		1.3		0.7		3.2		1.2	
1942-43	-3.3		-2.4		-0.7		-1.2		-4.0		0.5		3.7	
1943-44	-0.1		-0.1		1.5		-0.3		-1.8		4.8		0.8	

Table 10. Long term May mean departure, air temperature and rainfall (in.), 1891-1940 (U. S. Weather Bureau, 1940); mean Virginia 64.1°F., 3.71 in. (50 yrs), mean Maryland 62.6°F, 3.50 in. (46 yrs)(U. S. Weather Bureau, 1940). VA degree days departure, CDD and HDD, from 65°F, W. A. Van Engel from U. S. Weather Bureau, Climatological Data, 1897-1939.

Cal. Year	Temp. °F VA	Temp. °F MD	CDD VA	HDD VA	Rain VA	Rain MD	Cal. Year	Temp. °F VA	Temp. °F MD	CDD VA	HDD VA	Rain VA	Rain MD
1891	-2.9	.	.	.	1.02	.	1916	2.5	2.0	147.5	.	0.21	0.11
1892	0.7	.	.	.	-0.48	.	1917	-5.0(1)	-5.3(1)	60.0	.	-0.69	-0.48
1893	-0.9	.	.	.	2.14(2)	.	1918	4.5(2)	5.1(2)	191.5	.	0.47	0.29
1894	2.0	.	.	.	0.62	.	1919	0.3	0.2	130.5	.	1.58	1.83
1895	-1.8	-0.9	.	.	0.73	-0.23	1920	-4.2(1)	-4.1(1)	24.5	.	-1.84	-1.56
1896	4.6(2)	4.9(2)	.	.	0.55	-0.37	1921	-2.2	-1.3	59.0	120.0	0.90	1.97
1897	-1.2	-1.5	80.5	.	0.46	1.66	1922	1.2	2.1	112.5	22.5	0.46	-0.29
1898	1.5	0.4	116.0	.	1.66	1.00	1923	-1.8	-1.5	77.0	64.5	-1.80	-1.54
1899	1.6	1.0	106.5	.	-0.27	0.22	1924	-3.6	-3.9(1)	60.5	56.0	3.48(2)	3.10(2)
1900	0.6	0.5	117.5	.	-0.93	-1.10	1925	-4.3(1)	-3.8(1)	71.5	92.0	-1.54	-1.52
1901	-0.9	-1.3	51.0	.	2.05(2)	1.05	1926	0.0	0.6	90.5	71.5	-1.45	-1.52
1902	2.5	1.3	108.5	.	-1.00	-1.40	1927	0.2	-0.9	113.0	60.0	-0.84	-0.50
1903	0.8	1.4	111.0	.	-1.38	-0.86	1928	-1.9	-2.1	79.5	97.0	-1.08	-1.02
1904	-0.1	1.6	106.5	.	-0.61	-0.89	1929	-0.4	-0.6	110.5	61.5	1.06	-0.29
1905	2.5	2.1	144.0	.	1.05	-0.53	1930	2.7	2.2	158.5	32.0	-1.30	-1.39
1906	0.1	0.7	122.5	.	-0.73	-0.86	1931	-0.6	-0.4	97.0	67.0	1.42	1.04
1907	- 3.3	-4.5(1)	61.5	.	-0.17	1.04	1932	-0.3	-0.7	82.5	75.5	0.27	1.80
1908	0.3	0.8	170.5	.	0.99	2.68(2)	1933	3.9	2.2	209.5	25.0	1.58	1.95
1909	-1.0	-0.4	105.5	.	0.66	0.06	1934	1.2	1.3	126.0	63.0	0.40	1.14
1910	-3.1	-2.6(1)	.	.	-0.32	-0.51	1935	-2.3	-3.2(1)	81.5	82.0	-0.02	0.14
1911	3.4	5.0(2)	.	.	-2.68(1)	-2.39(1)	1936	2.2	2.3	127.5	36.0	-2.36(1)	-1.33
1912	0.7	1.5	.	.	0.92	0.62	1937	0.0	0.5	128.5	43.0	-0.93	-0.08
1913	0.1	0.0	.	.	1.77	0.81	1938	-0.5	-1.3	127.5	60.0	0.60	0.84
1914	1.5	2.5	157.5	.	-2.07(1)	-1.44	1939	1.3	2.4	190.0	103.5	-2.04(1)	-2.36(1)
1915	-0.5	-1.9	90.0	.	-0.41	0.32	1940	-1.7	-0.5	.	.	0.75	0.95

1. Temperature deficit (mean-60): VA > -4.1°F, 1.8°C; MD >-2.6°F, 1.0°C. Precipitation deficit: VA and MD arbitrary -2.0 in.
2. Excesses (greater than the mean), arbitrary: VA > 4.0°F, 2.0 in; MD > 4.0°F, 2.0 in.

Table 11. Deficits and excesses in precipitation, inches, July-October, March-May, 1919-1932, and during the water year, October 1 - September 30, 1919-1932. Deviations plus unless marked. U. S. Weather Bureau, 1919-1932, Climatological Data, Virginia and Maryland Sections. Deviations calculated by W. A. Van Engel.

	Virginia		Maryland		Bistate		Water Year	
Cal. Years	July to October	March to May	July to October	March to May	July to October	March to May	October-September VA	MD
1919-20	-1.44	-1.67	3.18	-0.86	1.74	-2.53	1.8	3.73
1920-21	0.17	-1.39	0.44	0.59	-0.61	-0.80	-7.05	-3.82
1921-22	-4.88	0.75	-2.18	-0.64	-7.06*	0.11	2.75	-0.02
1922-23	0.66	-0.58	-1.21	-0.17	-0.55	-0.75	-1.71	-3.73
1923-24	0.06	3.90*	-1.42	6.01*	-1.36	9.91*	4.97	8.61
1924-25	0.44	-4.26	-2.58	-4.10	-2.14	-8.36	-14.26	-12.33
1925-26	-7.22*	-4.25	-0.01	-4.66	-7.23*	-8.91	-3.92	1.70
1926-27	0.93	-1.24	5.68	-0.94	6.61	-2.18	-0.65	-2.65
1927-28	1.16	-0.80	0.35	+0.73	1.51	-0.07	7.82	11.32
1928-29	5.10	1.82*	4.16	2.22*	9.26	4.04*	-5.74	-4.77
1929-30	0.72	-4.02	-1.01	-3.76	-0.29	-7.78	-10.83	-11.99
1930-31	-9.30*	1.72	-10.10*	1.54	-19.40*	3.26	-2.27	3.14
1931-32	0.63	1.13	1.93	2.79	2.56	3.92	-7.77	-3.59

*Rainfall extremes associated with those river discharges that were favorable to strong year class development.

Table 12. River discharge, cfs, monthly means, low flow July-October, high flow March-May, calendar year ending. Susquehanna (Harrisburg, PA), low flow mean 13,993, high flow mean 64,338, 54 yrs; Potomac (Point of Rocks, MD), low flow mean 4,446, high flow mean 15,767, 50 yrs; James (Cartersville, VA), low flow mean 4,163, high flow mean 10,507, 46 yrs), calculated through May 1944. Flow < longterm mean marked -, Flow > longterm mean marked +. U. S. Geological Survey, 1958, 1960.

July-May Cycle. Years	Harrisburg Low flow Mean	Harrisburg High flow Mean	Pt. Rocks Low flow Mean	Pt. Rocks High flow Mean	Cartersville Low flow Mean	Cartersville High flow Mean
1891-92	24,275+(2)	69,667+	.	.	.	.
1892-93	14,250+	101,500+(2)	.	.	.	.
1893-94	13,850-	81,200+	.	.	.	.
1894-95	15,500+	64,900+	.	17,200+	.	.
1895-96	5,975-	57,700-	2,297-	7,957-(1)	.	.
1896-97	8,850-	67,667+	6,849-	18,210+	.	.
1897-98	10,200-	69,433+	3,428-	16,453+	.	.
1898-99	20,075+	66,700+	10,181+(2)	19,530+	.	15,222+
1899-00	6,675-	49,633-	2,216-	10,744-	2,603-	10,155-
1900-01	5,250-(1)	86,767+	1,901-(1)	26,823+(2)	2,696-	17,247+(2)
1901-02	21,125+	80,067+	7,749+(2)	29,664+(2)	8,847+(2)	12,827+
1902-03	35,225+(2)	67,667+	2,452-	20,614+	3,393-	15,516+(2)
1903-04	32,425+(2)	75,533+	6,367+	9,313-	5,087+	8,724-
1904-05	13,625-	57,633-	2,414-	11,518-	1,783-(1)	8,977-
1905-06	16,850+	55,333-	5,528+	14,626-	6,457+	9,735-
1906-07	14,900+	52,033-	10,039+(2)	18,833+	10,127+(2)	11,007+
1907-08	14,200+	90,033+(2)	4,925+	23,633+(2)	4,270+	11,733+
1908-09	6,600-	61,733-	3,408-	11,353-	4,668+	11,700+
1909-10	5,150-(1)	69,067+	2,195-(1)	8,527-(1)	2,575-	6,750-
1910-11	6,350-	44,733-	2,700-	9,700-	3,460-	8,320-
1911-12	21,800+	82,900+	6,428+	21,133+	2,740-	18,067+(2)
1912-13	18,175+	57,033-	5,365+	15,967+	2,900-	15,300+(2)
1913-14	10,125-	88,333+	4,030-	16,600+	3,513-	9,167-
1914-15	8,125-	30,567-(1)	1,860-(1)	6,167-(1)	1,990-(1)	5,137-(1)
1915-16	30,300+(2)	80,500+	5,380+	17,483+	5,093+	6,697-
1916-17	12,825-	50,233-	3,823-	18,230+	4,630+	13,523+
1917-18	27,700+(2)	70,200+	3,415-	19,797+	2,123-	13,917+
1918-19	14,150+	61,733-	2,980-	13,287-	2,900-	11,263+
1919-20	12,625-	74,033+	3,623-	18,500+	5,528+	9,430-
1920-21	16,575+	54,567-	4,655+	12,847-	5,425+	6,680-
1921-22	9,300-	60,033-	3,393-	13,477-	1,596-(1)	13,150+
1922-23	11,625-	57,433-	2,378-	8,807-	3,165-	9,727-
1923-24	6,700-	75,600+	2,308-	20,033+	2,665-	13,967+
1924-25	22,050+	34,367-(1)	5,478+	8,990-	6,943+	4,813-(1)
1925-26	10,048-	47,900-	1,928-(1)	8,950-	1,172-(1)	6,453-
1926-27	19,853+	70,567+	6,755+	17,233+	2,095-	9,160-
1927-28	20,143+	67,133+	5,065+	19,000+	4,658+	9,007-
1928-29	21,768+	92,233+(2)	5,438+	22,233+	9,598+(2)	15,500+(2)
1929-30	11,135-	46,933-	5,530+	7,237-(1)	4,735+	5,633-(1)
1930-31	4,495-(1)	57,000-	853-(1)	11,267-	677-(1)	7,253-
1931-32	7,720-	53,700-	3,113-	18,167+	2,495-	10,180-
1932-33	8,933-	69,133+	2,548-	24,667+(2)	3,001-	13,313+
1933-34	22,338+	42,397-(1)	5,724+	8,539-(1)	2,648-	9,615-
1934-35	12,055-	60,870-	3,546-	16,503+	3,826-	14,180+
1935-36	14,018+	101,080+(2)	4,568+	31,514+(2)	5,913+	15,279+
1936-37	6,327-	57,567-	2,888-	18,183+	2,574-	11,104+
1937-38	18,425+	44,320-(1)	10,198+(2)	9,191-	8,986+(2)	6,110-(1)
1938-39	11,548-	55,270-	3,231-	14,101-	5,653+	7,879-
1939-40	4,748-(1)	92,830+(2)	4,245-	16,972+	3,553-	8,633-
1940-41	9,911-	42,933-(1)	5,166+	9,758-	8,203+(2)	5,980-(1)
1941-42	5,768-(1)	67,143+	3,044-	13,890-	2,453-	7,893-
1942-43	17,826+	78,147+	13,477+(2)	16,023+	4,652+	10,765+
1943-44	8,284-	68,627+	2,394-	17,900+	2,247-	10,623+

(1) Among the five historical lows. (2) Among the five historical highs.

Table 13. Categories of river discharge, cfs, Summer low flow, July-October; Spring high flow, March-May. Susquehanna River (S), low flow mean 13,993, high flow mean 64,538; Potomac River (P), low flow mean 4,446, high flow mean 15,767; James River (J), low flow mean 4,163, high flow mean 10,507. Derived from Table 12. (1) Summer flow slightly larger than the mean; (2) spring flow slightly smaller than the mean. Years are the yearclass year and the year following.

Years	Sum L/ Spr H	Sum L/ Spr L	Sum H/ Spr L	Sum H/ Spr H
1900-01	S.P.J	.	.	.
1901-02	.	.	.	S.P.J
1902-03	P.J	.	.	S
1903-04	.	.	P.J	S
1904-05	.	S.P.J	.	.
1905-06	.	.	S.P.J	.
1906-07	.	.	S	P.J
1907-08	S.P.J (1 1 1)	.	.	.
1908-09	.	S.P	.	J
1909-10	S	P.J	.	.
1910-11	.	S.P.J	.	.
1911-12	J	.	.	S.P
1912-13	J	.	S	P
1913-14	S.P	J	.	.
1914-15	.	S.P.J	.	.
1915-16	.	.	J	S.P
1916-17	P.J (1)	S	.	.
1917-18	P.J	.	.	S
1918-19	J	S.P (1)	.	.
1919-20	S.P	.	J	.
1920-21	.	.	S.P.J	.
1921-22	J	S.P	.	.

Years	Sum L/ Spr H	Sum L/ Spr L	Sum H/ Spr L	Sum H Spr H
1922-23	.	S.P.J.	.	.
1923-24	S.P.J	.	.	.
1924-25	.	.	S.P.J	.
1925-26	.	S.P.J.	.	.
1926-27	.	J	.	S.P
1927-28	.	.	J	S.P
1928-29	.	.	.	S.P.J
1929-30	.	S	P.J	.
1930-31	.	S.P.J	.	.
1931-32	P	S.J	.	.
1932-33	S.P.J	.	.	.
1933-34	.	J	S.P	.
1934-35	P.J	S	.	.
1935-36	.	.	.	S.P.J
1936-37	P.J	S	.	.
1937-38	.	.	S.P.J	.
1938-39	.	S.P.	J	.
1939-40	S.P	J	.	.
1940-41	.	S	J.P	.
1941-42	S	P.J	.	.
1942-43	.	.	.	S.P.J
1943-44	S.P.J	.	.	.

Table 14. Magnitudes and frequency of floods, thousands of cubic feet per second, cfs, of the Susquehanna (Harrisburg), Potomac (Point of Rocks) and James (Cartersville) rivers, 1786-1945. Speer and Gamble, 1964; Tice, 1968.

	Susquehanna			Potomac			James	
Cal. Year	Date	cfs	Year	Date	cfs	Year	Date	cfs
1786	October 5	482						
1846	March 15	482						
1865	March 18	573				1870	November	N/A
1868	March 19	417				1877	November 24	N/A
1886	January 6	385						
1889	June 2	654	1889	June 2	460			
1891	February 19	408						
1893	May 5	324						
1894	May 22	613						
1898	March 24	315				1899	March 6	111
1902	March 3	449	1902	March 2	219	1901	May 23	134
1904	March 8	631(1)				1901	December 30	130
1905	March 21	306						
1910	March 3	332						
1913	March 28	402						
1914	March 30	358						
1916	March 29	379						
1916	June 18	300						
1920	March 13	423						
1924	April 8	324	1924	May 13	277	1924	May 13	106
1925	February 13	379				1924	October 1	103
1926	November 17	323.5				1934	December 2	104
1936	March 17-19	992(2)	1936	March 19	480	1935	September 6	134
1940	April 2	418	1937	April 27	310	1936	March 19	166
1943	January 1	412	1942	October 16	418	1937	April 26	133
						1940	August 17	145
						1942	October 16	135
						1944	September 20	180

(1) McCall Ferry, PA
(2) 1,130 at Conowingo Dam

Table 15. Virginia crab licenses, 1921-1941. Virginia Commission of Fisheries reports, compiled by W. A. Van Engel.

Fiscal Year End (1)	Crabber (2)	Patent trotline	No of pots	Dredge (3)	Total Crabbers (4)	Picking Crating Packing House	Canner	Buyer	Fiscal Year End
1921	1873	.	.	45	1918	49	.	69	1921
1922	1957	.	.	.	(2571)	(68)	.	(139)	1922
1923	.	.	.	.	(2602)	(66)	.	(102)	1923
1924	.	.	.	.	(1811)(5)	(22)	.	(55)	1924
1925	.	.	.	.	2884	91	.	134	1925
1926	.	.	.	.	(3286)	(50)	.	(100)	1926
1927	.	.	.	.	2940	70	.	149	1927
1928	.	.	.	.	2559	80	.	110	1928
1929	.	.	.	.	1829	75	.	104	1929
1930	.	.	.	.	2170	119	.	116	1930
1931	(1272)	(4)	.	.	1296	59	(2)	105	1931
1932	(1026)	(69)	.	.	1157	40	(2)	106	1932
1933	(1067)	(50)	.	.	1200	38	(2)	100	1933
1934	(992)	(36)	.	.	1142	65	(1)	105	1934
1935	(1688)	(73)	.	.	1899	67	(0)	118	1935
1936	(1514)	(44)	.	.	1654	61	(1)	144	1936
1937	(1871)	(87)	.	.	2162	85	(1)	130	1937
1938	(1816)	(68)	370	213	1779	87	(1)	120	1938
1939	(1615)	(77)	94	228	1907	66	(0)	115	1939
1940	1100	(28)	2780	177	N/A	83	(0)	121	1940
1941	1495	(78)	20265	155	N/A	99	(0)	158	1941

(1) Fiscal year Oct 1-Sep 30, 1919-1923; Oct 1-Jun 30, 1923-1924; July 1-Jun 30, 1924-1941.
(2) Number of gear in parentheses are estimates from revenue.
(3) Soft and hard crab scrapes and dredges were usually not separated.
(4) Total number of crabbers cannot be reconciled from data given in reports.
(5) Nine-month fiscal year in 1924.

Table 16. Virginia crab licenses, 1921-1941. Virginia Commission of Fisheries license receipts, 1921-1940. Compiled from unpublished data by W. A. Van Engel.

Cal. Year	Crabber (1)	Patent Trot-line	Potter	Scrape (2)	Dredge	Total Crabbers	Picking Crating Packing House	Canner	Buyer	Cal. Year
1921	1819	2	.	11	27	1859	49	2	69	1921
1922	(2135)	(2)	.	(3)	(26)	(2166)	(51)	(2)	(131)	1922
1923	(1865)	(8)	.	(1)	(53)	(1927)	(62)	(2)	(77)	1923
1924	(2065)	(47)	.	(11)	(55)	(2178)	(52)	(2)	(96)	1924
1925	(2859)	(25)	.	(16)	(59)	(2958)	(70)	(2)	(126)	1925
1926	2711	48	.	(6)	(60)	2825	75	2	131	1926
1927	2668	40	.	(3)	(64)	2775	84	2	130	1927
1928	2139	43	1	(11)	(67)	2139	71	2	111	1928
1929	1408	36	38	(14)	(67)	1563	66	2	93	1929
1930	1537	48	.	(6)	(52)	1643	75	2	97	1930
1931	1464	44	.	(4)	(61)	1573	60	2	115	1931
1932	1051	67	.	(5)	(60)	1183	48	3	102	1932
1933	1066	54	.	(38)	(54)	1212	59	2	108	1933
1934	1610	69	.	38	70	1787	66	0	132	1934
1935	1698	62	1	42	92	1895	70	0	122	1935
1936	1601	52	3	13	87	1756	74	0	171	1936
1937	1677	62	8	93	101	1957	76	1	122	1937
1938	1699	70	73	115	80	2041	76	1	122	1938
1939	1255	77	109	146	79	1666	77	1	122	1939
1940	1261	46	349	18	96	1770	85	0	138	1940
1941	945	60	476	136	70	1687	92	0	108	1941

(1) Number of gear in parentheses are estimates from revenue.
(2) Soft and hard crab scrapes were similarly taxed and not separated in this report.

Table 17. Maryland crab licenses, 1916-1941. Annual Reports of the Conservation Department, the Department of Tidewater Fisheries, and the Board of Natural Resources of Maryland, and the National Marine Fisheries Service.

Cal. Year	Crabber (1)	Trotline		Pot		Dipnet	Trap		Scrape		Cal. Year
		No. of Men	No. of Lines	No. of Men	No. of Pots	No. of Men	No. of Men	No. of Traps	No. of Men	No. of Scrapes	
1916	3500	-	-	-	-	-	-	-	730	-	1916
1917	1709	-	-	-	-	-	-	-	378	-	1917
1918	1814	-	-	-	-	-	-	-	402	-	1918
1919	2375	-	-	-	-	-	-	-	407	-	1919
1920	2055	-	-	-	-	-	-	-	455	-	1920
1921	2695	-	-	-	-	-	-	-	533	-	1921
1922	2912	-	-	-	-	-	-	-	460	-	1922
1923	2553	-	-	-	-	-	-	-	420	-	1923
1924	2668	-	-	-	-	-	-	-	389	-	1924
1925	2515	-	-	-	-	-	-	-	406	-	1925
1926	2018	-	-	-	-	-	-	-	291	-	1926
1927	2235	-	-	-	-	-	-	-	279	-	1927
1928	2275	-	-	-	-	-	-	-	270	-	1928
1929	2390	-	-	-	-	-	-	-	223	-	1929
1930	2795	-	-	-	-	-	-	-	215	-	1930
1931	3012	1456	1560	-	-	1776	-	-	605	1098	1931
1932	2562	1251	1227	-	-	1523	-	-	431	956	1932
1933	3121	1307	1547	-	-	1458	-	-	397	642	1933
1934	2041	1268	1531	-	-	1321	-	-	321	582	1934
1935	2602	1410	1731	-	-	1220	-	-	334	708	1935
1936	2427	1618	1881	-	-	983	-	-	344	708	1936
1937	2086	1376	1586	-	-	863	-	-	296	632	1937
1938	2004	1471	1766	9	55	670	-	-	307	614	1938
1939	2441	1523	1851	-	-	484	8	31	274	548	1939
1940	2116	1341	1695	18	515	449	19	97	224	448	1940
1941	1296	1041	1296	17	575	341	-	-	98	195	1941

(1) Crabbers license permits the use of any gear not otherwise prohibited or provided for.

Table 18. Environmental conditions in year class year and spring following: departures of mean May state air temperatures °F (T) from long term means; cooling degree days (CDD), Norfolk; departures of mean May and June surface water temperatures °F (SWT) from long term means, Baltimore (B) 1914-1941, Windmill Point (W) 1882-1922. River discharges (DSCG), summer (SU) July-October in year class year, spring (SP) March-May in year following, L (Low) is smaller than mean cfs, H (High) is larger than the mean cfs, Susquehanna (S), Potomac (P), James (J) rivers. Mean Index and No. Cases exclude annual trotlines (TrYrVA, TrYrMD, TrYrVAMD, TrYrMDt, TrYrMDts), and ScDMD, DipMD; ScVA are included. Total bay annual landings, millions of pounds (M), for the year following the year class year. Data extracted from Tables 1, 7, 8b, 9, 10, 13. Environmental data for 1944-45 not available. See text for further details.

	T May VA	T May MD	CDD	SWT May B	SWT May W	SWT Jun B	SWT Jun W	DSCG SU L SP H	DSCG SU L SP L	DSCG SU H SP L	DSCG SU H SP H	Mean Catch Index	No. Cases	Total Landings	Year Class
Mean T	64.1	62.6		64.1	62.1	74.0	71.9								
Years															
1930-31	2.7	2.2	158.5	1.4	.	0.7	.	.	S.P.J	.	.	1.47	4	65	1930
1929-30	-0.4	-0.6	110.5	-0.2	.	0.1	.	.	S	P.J	.	1.13	1	69	1929
1906-07	0.1	0.7	122.5	.	-0.5	.	0.0	.	.	S	P.J	1.06	1	.	1906
1941-42	.	.	.	-0.4	.	-1.0	.	S	P.J	.	.	1.02	9	36	1941
1905-06	2.5	2.1	144.0	.	2.9	.	-1.3	.	.	S.P.J	.	1.00	1	.	1905
1931-32	-0.6	-0.4	97.0	-0.4	.	-0.2	.	P	S.J	.	.	0.94	4	62	1931
1937-38	0.0	0.5	128.5	0.7	.	3.0	.	.	.	S.P.J	.	0.81	7	55	1937
1938-39	-0.5	-1.3	127.5	0.3	.	1.2	.	.	S.P	J	.	0.78	7	57	1938
1907-08	-3.3	-4.5	61.5	.	-5.7	.	-9.0	S.P.J	.	.	.	0.74	1	45	1907
1932-33	-0.3	-0.7	82.5	0.5	.	-0.2	.	S.P.J	.	.	.	0.73	4	56	1932
1935-36	-2.3	-3.2	81.5	-2.6	.	-0.6	.	.	.	.	S.P.J	0.66	7	44	1935
1928-29	-1.9	-2.1	79.5	-2.2	.	-3.1	.	.	.	.	S.P.J	0.66	1	60	1928
1934-35	1.2	1.3	126.0	-0.2	.	1.7	.	P.J	S	.	.	0.64	4	41	1934
1927-28	0.2	-0.9	113.0	-2.2	.	-3.1	.	.	.	J	S.P	0.62	1	.	1927
1921-22	-2.2	-1.3	59.0	-0.8	-1.3	0.8	-0.7	J	S.P	.	.	0.60	5	.	1921
1936-37	2.2	2.3	127.5	3.0	.	-0.1	.	P.J	S	.	.	0.57	7	49	1936
1943-44	.	.	.	0.5	.	3.7	.	S.P.J	.	.	.	0.54	7	45	1943
1925-26	-4.3	-3.8	71.5	-2.0	.	3.0	.	.	S.P.J	.	.	0.54	2	.	1925
1933-34	3.9	2.2	209.5	0.7	.	0.8	.	.	J	S.P	.	0.50	4	40	1933
1942-43	.	.	.	3.2	.	1.2	.	.	.	.	S.P.J	0.49	7	.	1942
1939-40	1.3	2.4	190.0	0.7	.	2.3	.	S.P	J	.	.	0.47	7	42	1939
1908-09	0.3	0.8	170.5	.	2.4	.	-0.2	.	S.P	.	J	0.46	1	.	1908
1909-10	-1.0	-0.4	105.5	.	-0.2	.	2.4	S	P.J	.	.	0.45	1	.	1909
1917-18	-5.0	-5.3	60.0	-5.8	-3.8	-0.4	-2.0	P.J	.	.	S	0.44	1	.	1917
1918-19	4.5	5.1	191.5	2.3	1.5	-0.6	-0.8	J	S.P	.	.	0.41	5	.	1918
1919-20	0.3	0.2	130.5	-0.8	-0.6	3.0	0.3	S.P	.	J	.	0.40	5	23	1919
1922-23	1.2	2.1	112.5	2.1	-0.1	1.9	-0.3	.	S.P.J	.	.	0.37	5	.	1922
1916-17	2.5	2.0	147.5	-0.6	0.3	-2.4	-1.2	P.J	S	.	.	0.34	1	.	1916
1924-25	-3.6	-3.9	60.5	-2.9	.	-3.5	.	.	.	S.P.J	.	0.34	3	30	1924
1914-15	1.5	2.5	157.5	1.6	2.1	0.8	1.0	.	S.P.J	.	.	0.30	1	50	1914
1940-41	-1.1	-0.5	.	-1.9	.	-0.1	.	.	S	J.P	P	0.29	7	30	1940
1920-21	-4.2	-4.1	24.5	-3.3	-4.2	-2.2	-2.1	.	.	S.P.J	.	0.29	5	.	1920
1915-16	-0.5	-1.9	90.0	0.7	-0.7	-1.3	-3.1	.	.	J	S.P	0.25	2	46	1915
1926-27	0.0	0.6	90.5	-1.5	.	-4.6	.	.	J	.	S.P	0.24	1	.	1926
1913-14	0.1	0.0	.	.	0.9	.	0.3	S.P	J	.	.	0.23	1	.	1913
1923-24	-1.8	-1.5	77.9	-1.0	.	1.2	.	S.P.J	.	.	.	0.19	4	25	1923
Unknown indices															
1904-05	-0.1	1.6	106.5	.	0.0	.	0.8	.	S.P.J	.	.	.	.	.	1904
1910-11	-3.1	-2.6	.	.	-2.3	.	-6.3	.	S.P.J	.	.	.	.	.	1910
1911-12	3.4	5.0	.	.	7.1	.	1.0	J	.	.	S.P	.	.	.	1911
1912-13	0.7	1.5	.	.	3.6	.	-0.5	J	.	S	P	.	.	.	1912

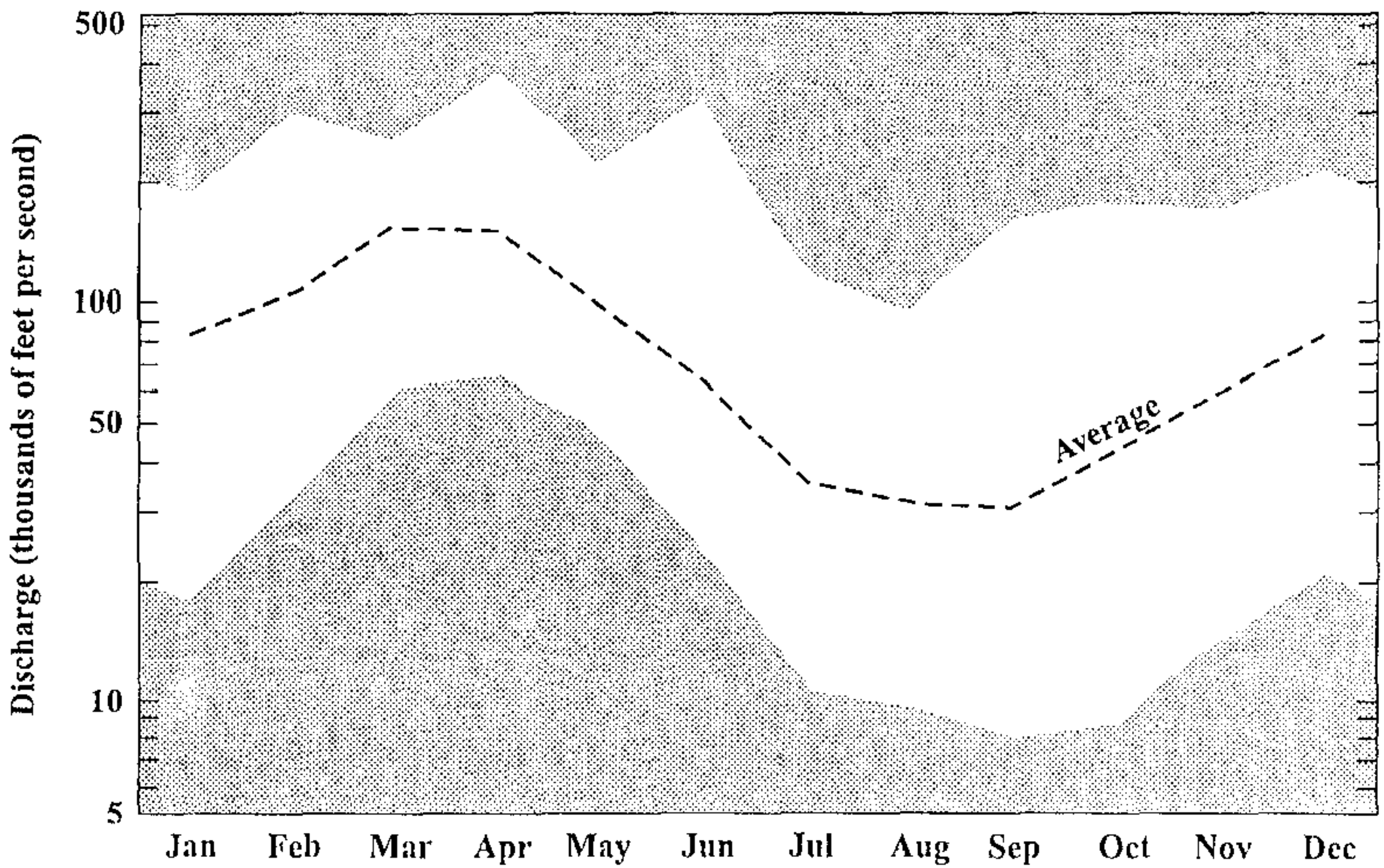

Figure 1. Monthly Mean Streamflow Into Chesapeake Bay. Unshaded area shows range between highest and lowest monthly mean flows for the period of record, January 1951-1995.

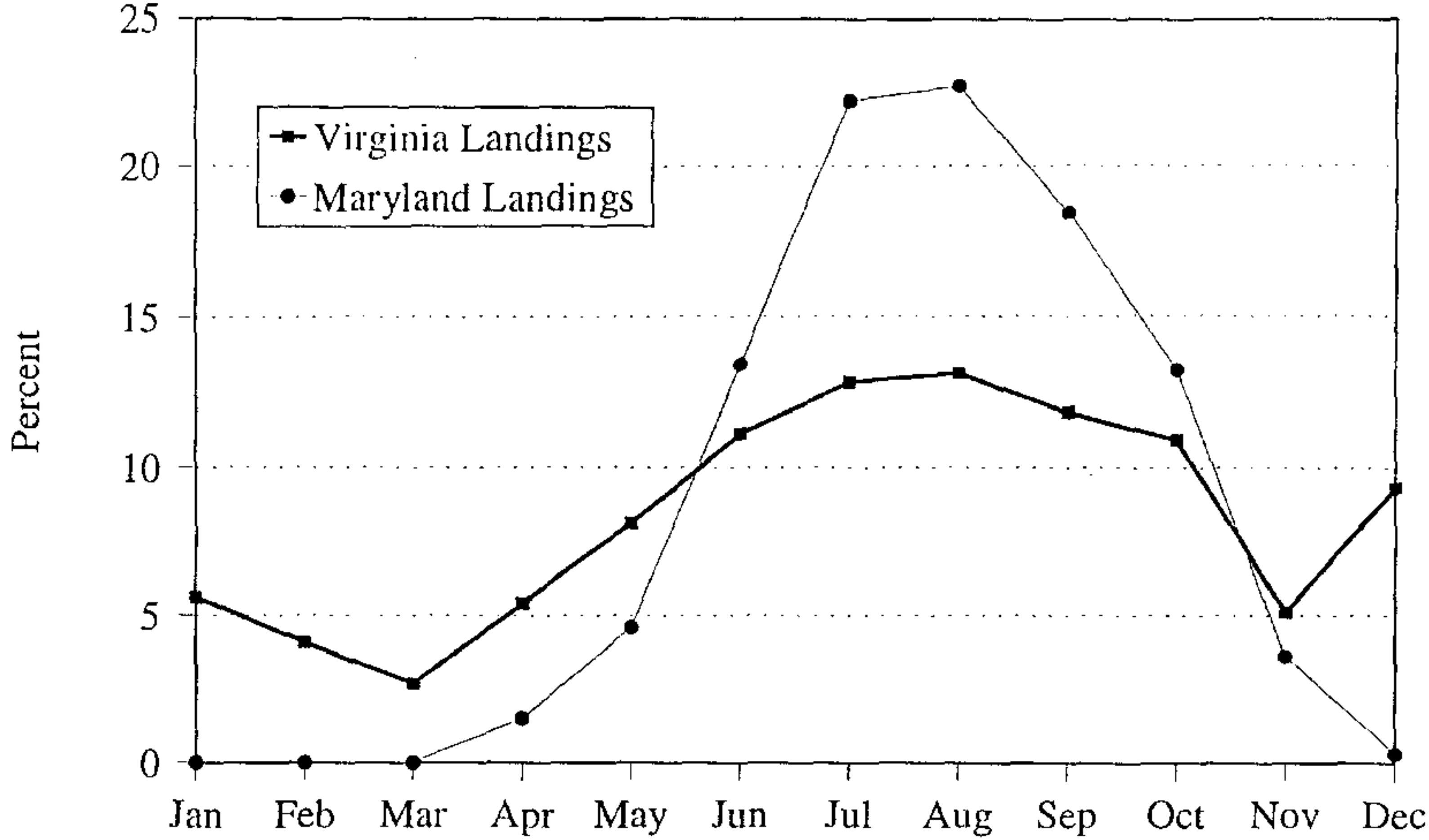

Figure 2. Annual blue crab landings by state, 1960-1987.

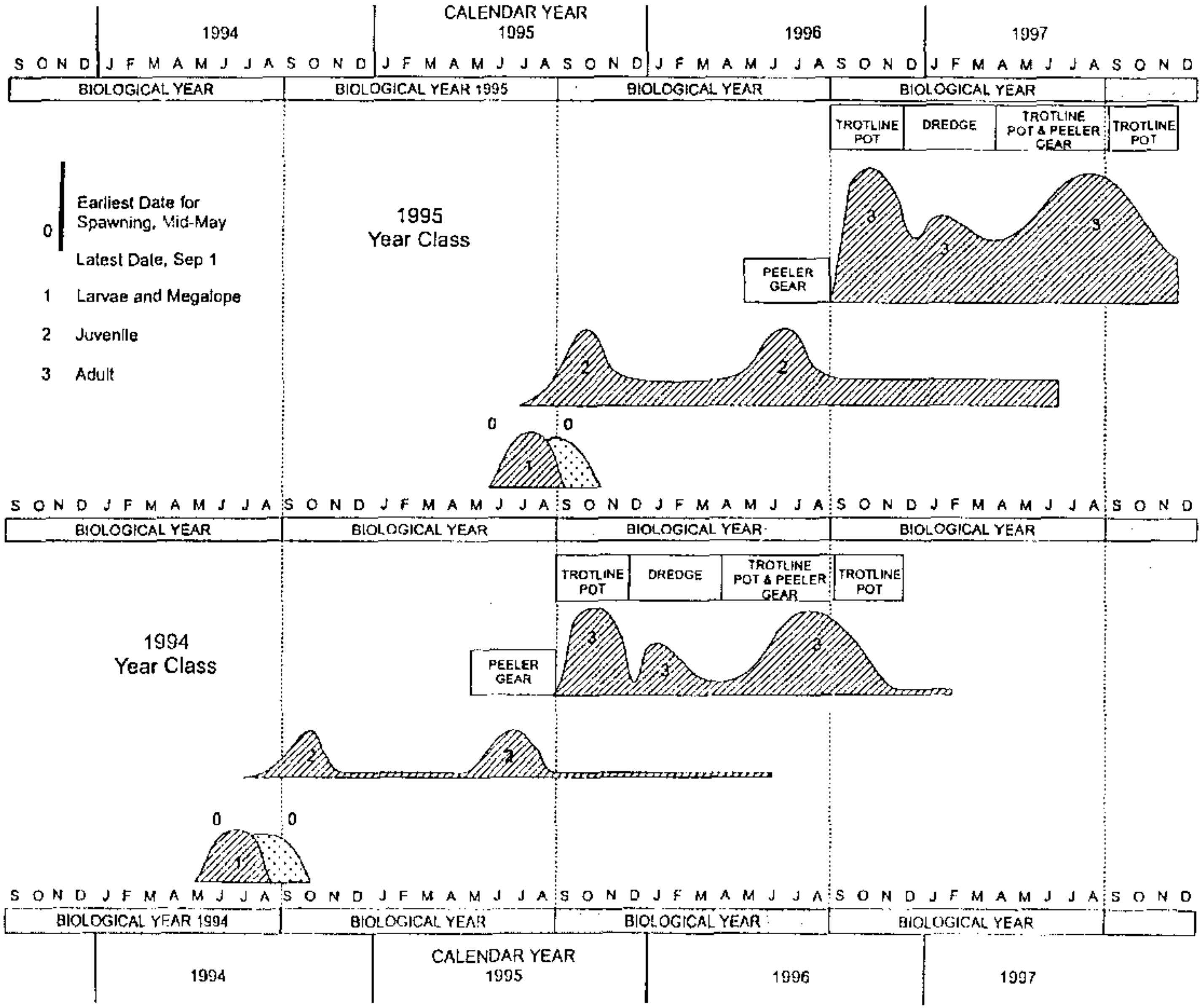

Figure 3. Generalized time relationships between the developmental stages in the life history of the blue crab.

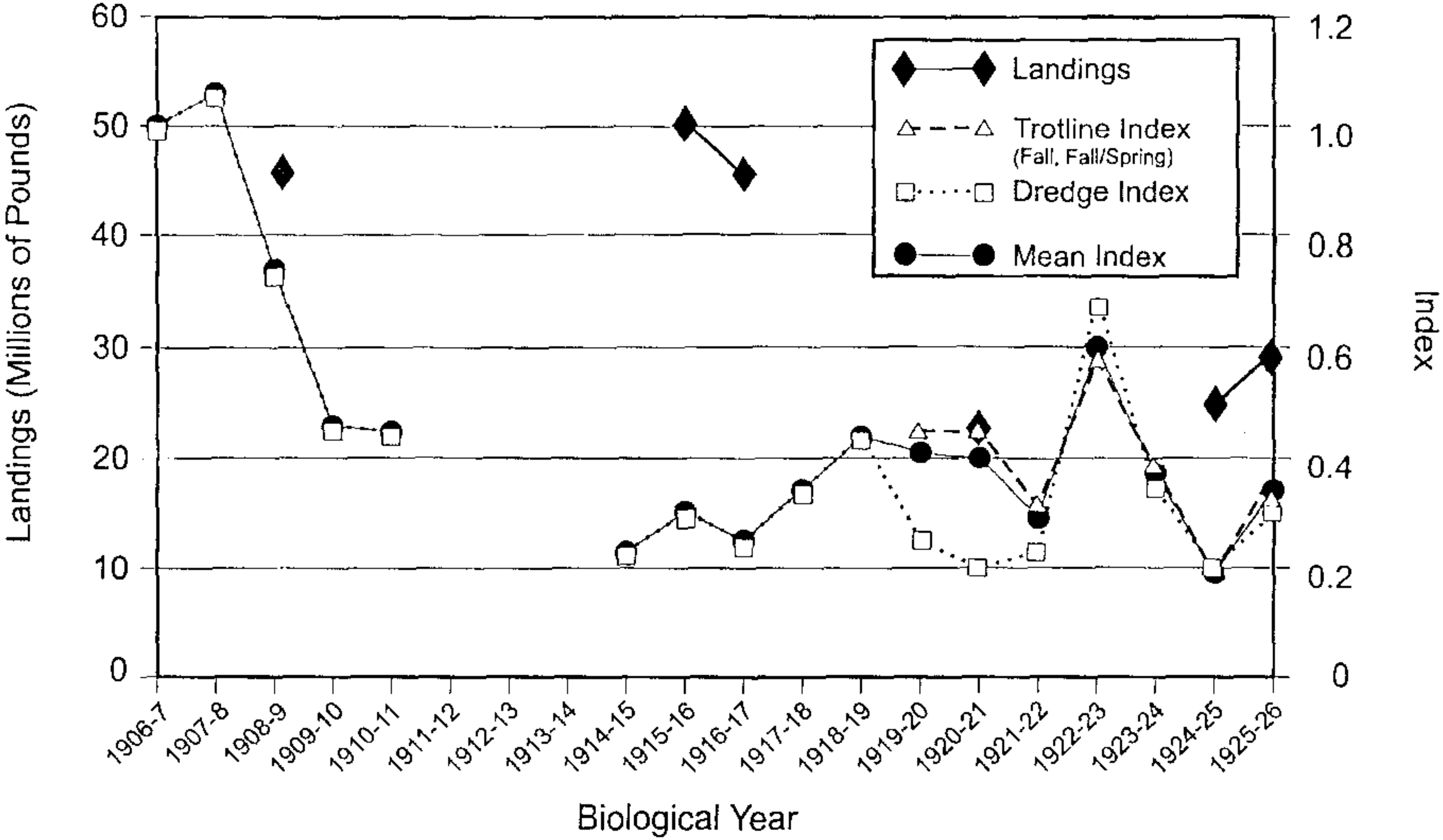

Figure 4. Bay landings and indices of hard crabs for years 1906-07 through 1925-26.

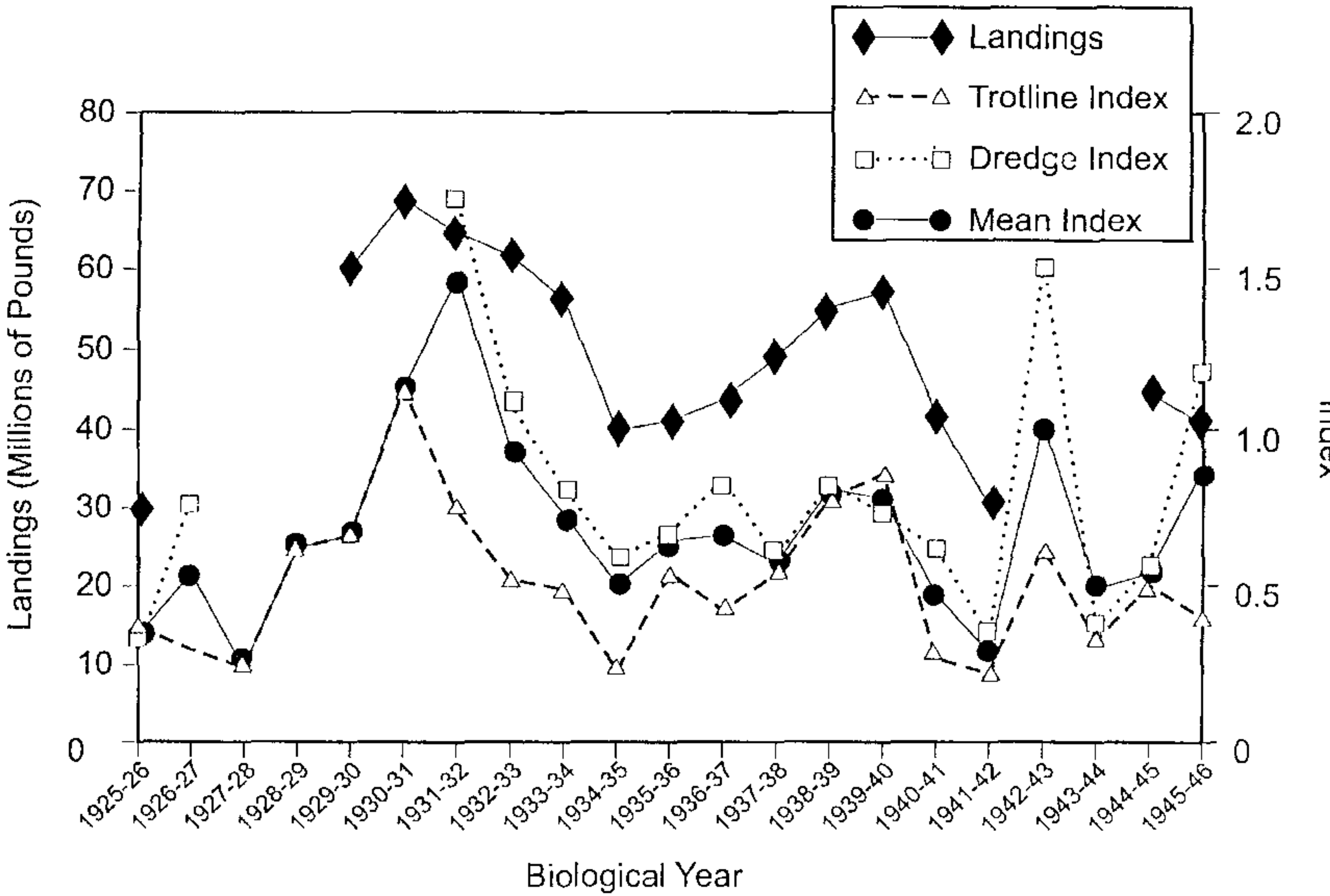

Figure 5. Bay landings and indices of hard crabs for years 1925-26 through 1945-46.

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